Gowanus Canal Superfund CSO Project
Tunnel Storage System Alternative

EPA Technical Workshop

July 17, 2018

Agenda

- Objective
- Background
- Issues Affecting Gowanus
- Tunnel Concept
  - Approach
  - Components
  - Construction
- Comparison of Cost and Benefits, Schedule
- Next Steps

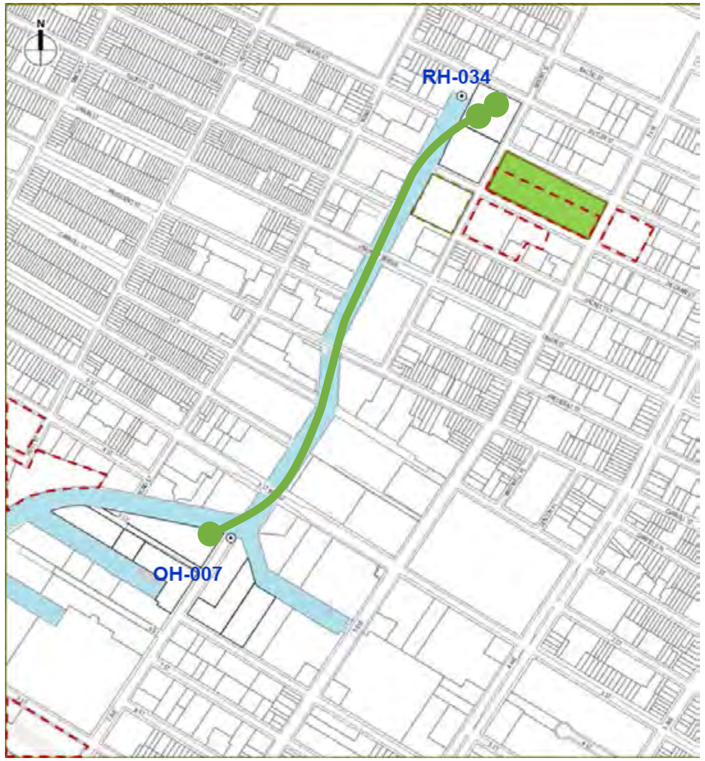
Objective

Current Plan: Deliver 2 CSO Retention Tanks for Gowanus Canal

Proposed Plan: Pivot to Tunnel Storage Concept to provide additional benefits and serve a wider area around the Gowanus Canal

Why Pivot?

- Use modern storage tunnel system design rather than older tank technology.
  - DEP is doing tunnels for Flushing Bay and Newtown Creek CSO LTCPs.
  - Consistent with National / International approach for CSO / wet weather issues
- 234 Butler can remain unaltered with a tunnel shaft near the head of the canal rather than a tank head-house.
- Initial Tunnel phase will cost same as tanks: $1.2B
- Similar implementation timeframe but:
  - ✓ Tunnel reduces annual CSO events from 10 to 7. (further reduced to 4 with $200M Phase 1b.)
  - ✓ Tunnel is scalable; future extensions can capture even more CSO, reduce street flooding, and help resiliency.
  - ✓ Less construction disruption in neighborhood.
  - ✓ Reduced presence during construction and operation.
  - ✓ Potentially more public green space along the canal.
  - ✓ No additional property acquisition required for 1st Phase.



CSO Mitigation Toolbox

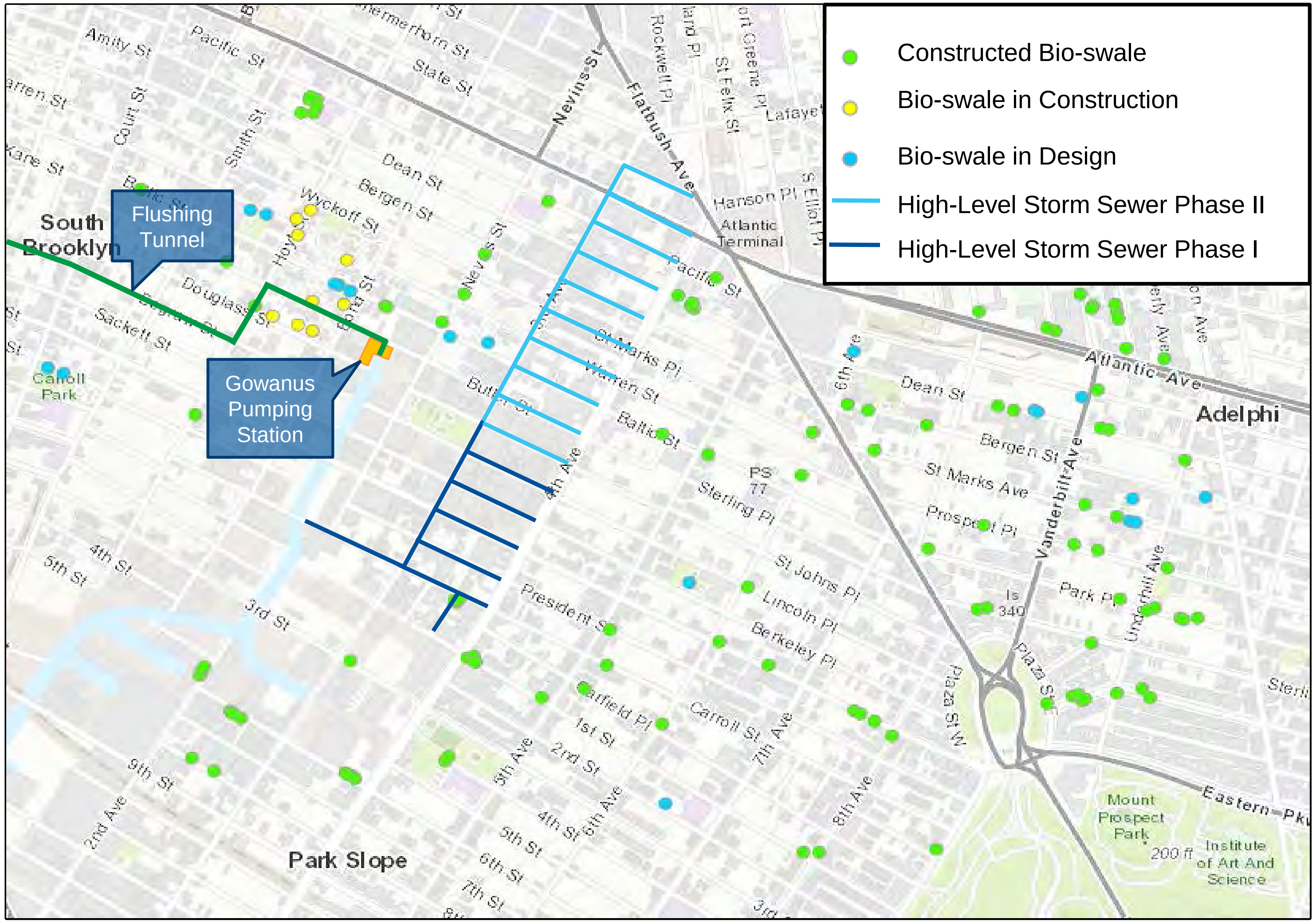
INCREASING COMPLEXITY

INCREASING COST

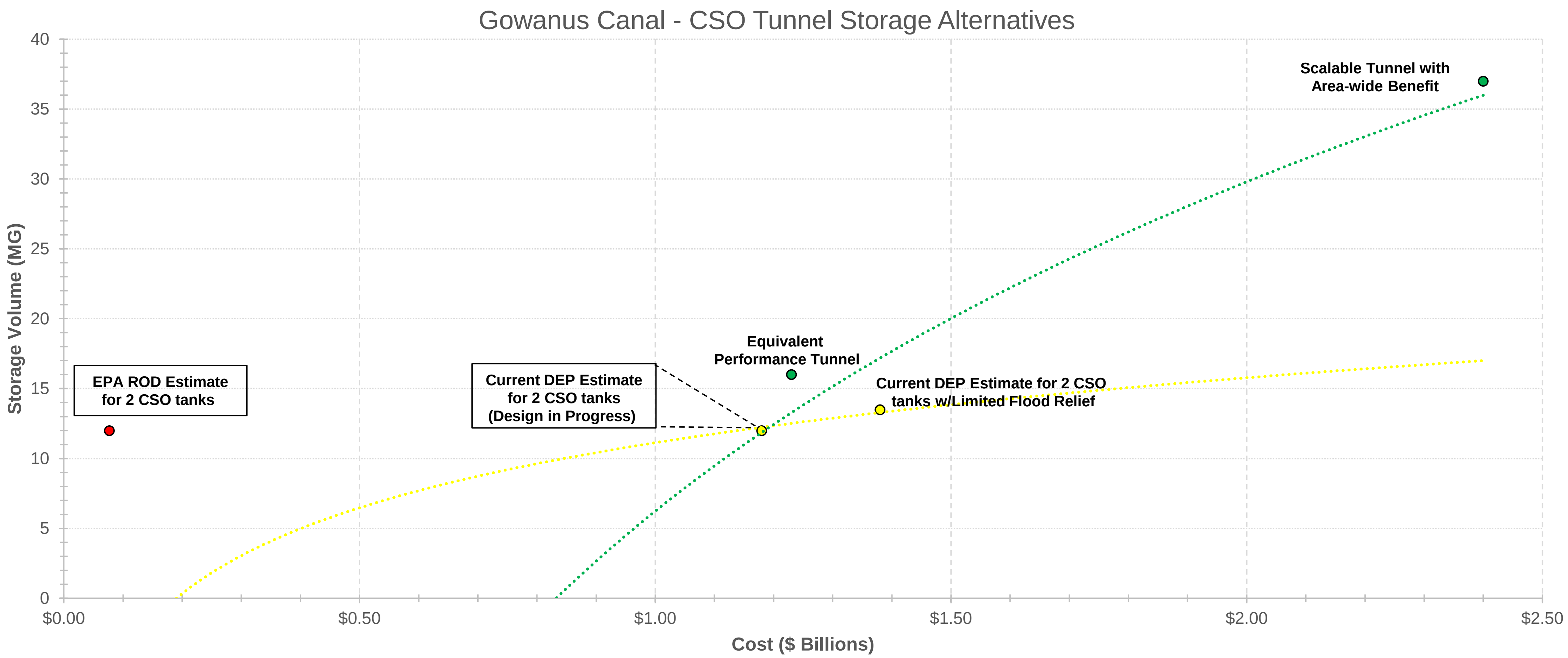
System Optimization	Fixed Weir	Parallel Interceptor / Sewer	Inflatable Dams Bending Weirs Control Gates	Pump Station Expansion
CSO Relocation	Gravity Flow Tipping to Other Watersheds	Pumping Station Modification	Flow Tipping with Conduit/Tunnel and Pumping	
Water Quality / Ecological Enhancement	Floatables Control	Dredging	Dissolved Oxygen Improvement	Flushing Tunnel
Treatment ***Satellite:***	Outfall Disinfection	Retention Treatment Basin (RTB)		High Rate Clarification (HRC)
Centralized:	WWTP Expansion			
Storage	In-System	Shaft	Tank	Tunnel

Background - Recent DEP Upgrades in Gowanus Canal Watershed

- Gowanus Canal **Waterbody/Watershed Facility Plan (WWFP)** $200M of Canal improvements:
  - **Gowanus Pumping Station** & **Flushing Tunnel** (both activated in 2014)
  - Overall ***44%* reduction** in annual average **CSO volume** from Pre-WWFP
  - Accomplished primary contact compliance for water quality (reduction in pathogens and ***32-93%* increase in dissolved oxygen**)
  - Mitigated floatables and odor substantially
- **Green Infrastructure (GI)**
  - Design & Construction – $7.3 M (Ongoing)
- **High Level Storm Sewer (HLSS)**
  - HLSS Area I – $28 M (Fall 2018)
  - HLSS Area II – $19 M (Approx. Early 2020)



Cost ($B) vs. Storage Volume (MG)

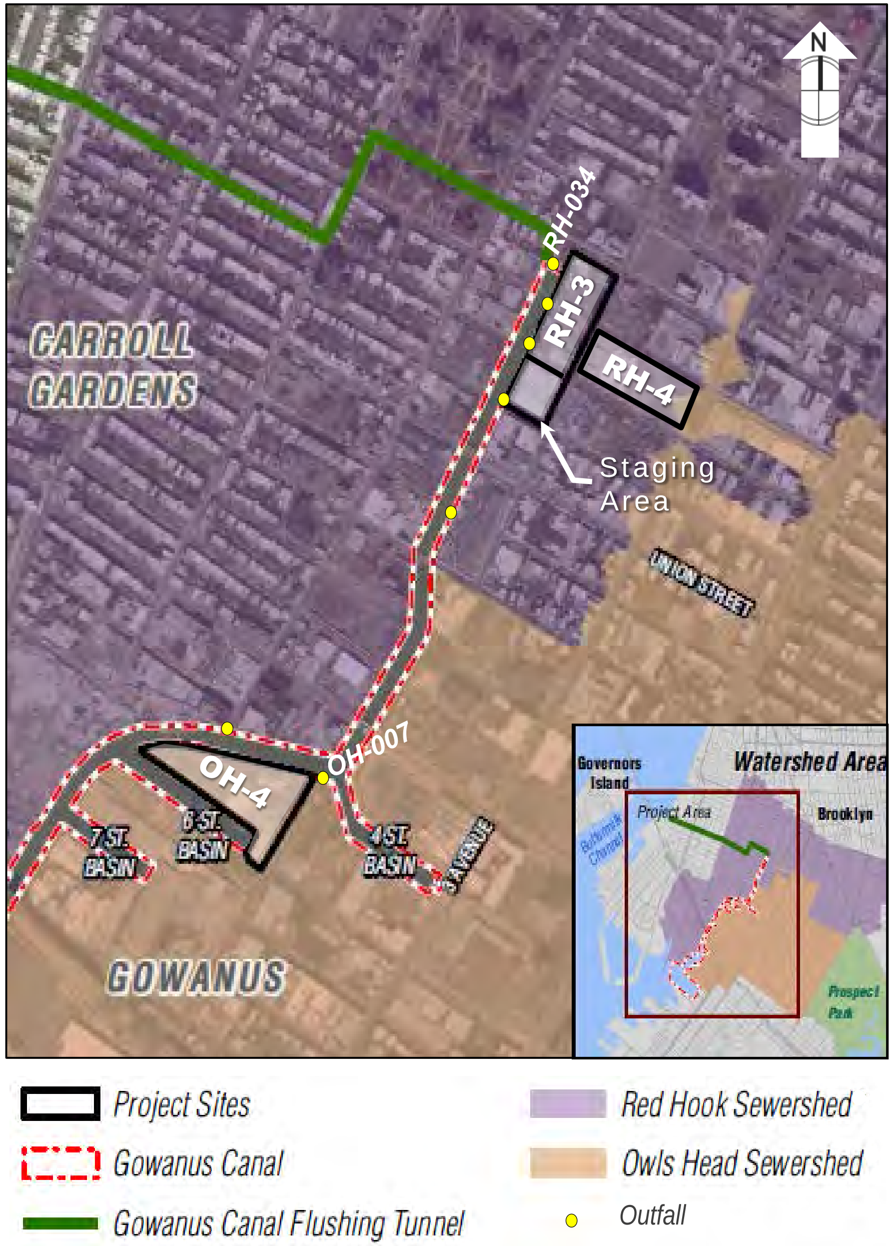


Background & Status - CSO Tanks Project

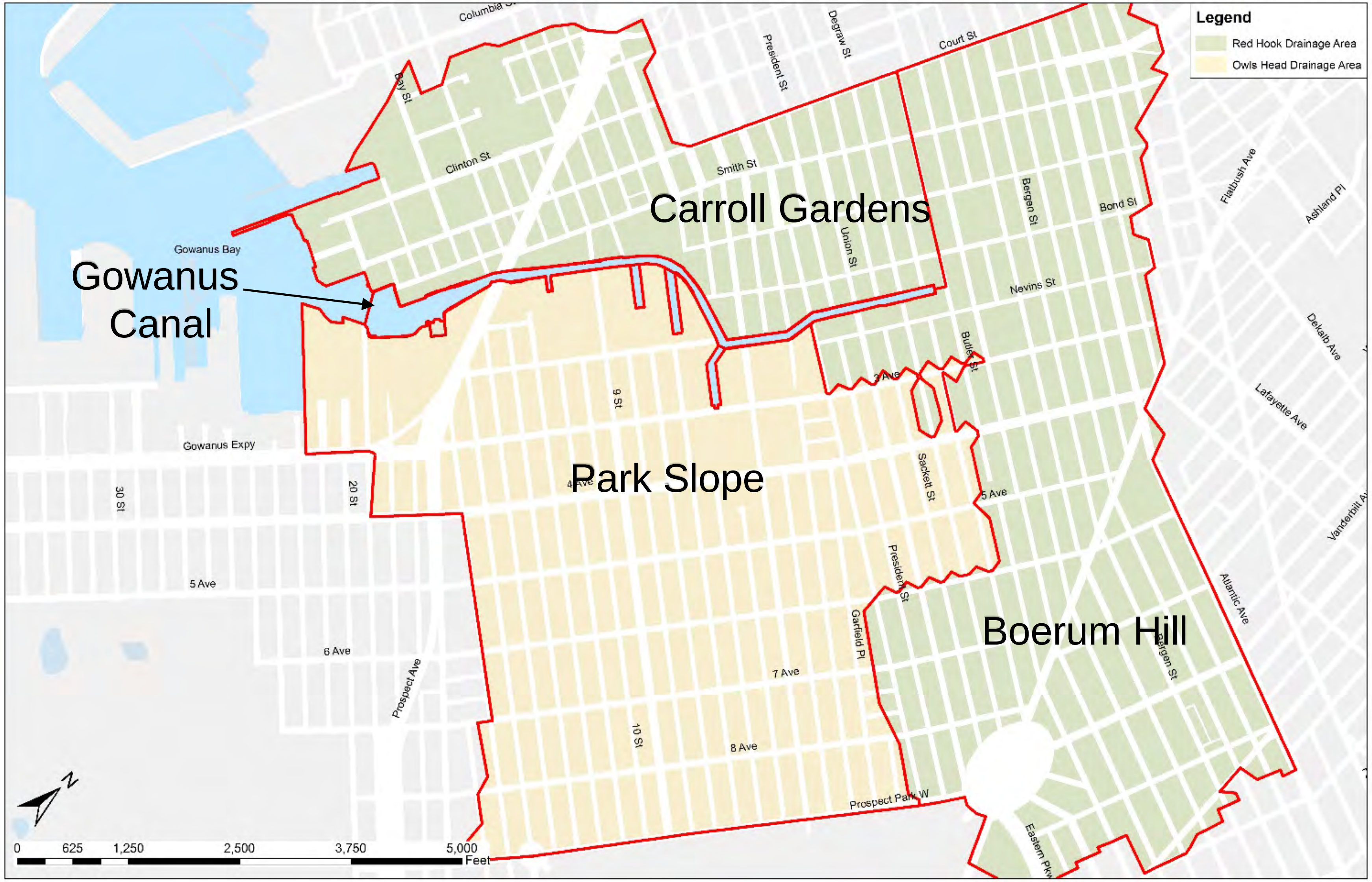
- DEP is **required** to provide a total of **12 million gallons (MG) of CSO storage** by constructing two CSO facilities:
  - **8 MG tank** for **Outfall RH-034** at the RH-3 (Head-End) Site or the RH-4 (Park) Site (parallel designs); and
  - **4 MG tank** for **Outfall OH-007** at the OH-4 Site.

	Milestone Description	Status – Date
2016 Settlement Agreement	EIS for CSO Tanks	Completed – February 2018
2016 Settlement Agreement	RH-3 ULURP	Completed – April 2018
2016 Settlement Agreement	RH-3/4 CP-1 Design (Site prep / Demo)	Completed – June 2017
2016 Settlement Agreement	RH-3/4 CP-2 Design (Excavation / Substructures)	Underway – April 2019
2016 Settlement Agreement	RH-3/4 CP-3 Design (Superstructure / Mech Fitout)	Underway – September 2019
2016 Settlement Agreement	RH-3 Property Acquisition	Underway – April 2020
	OH-007 Design Procurement	Underway – FY 2019

Budget Forecast	
Spent to date June 2018	$25M
Projected through September 2019	$49M

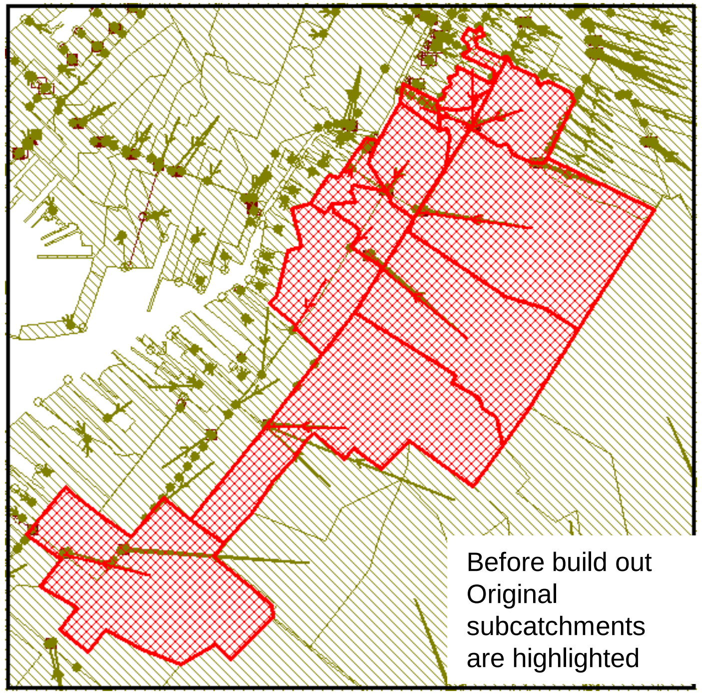


Study Area Map

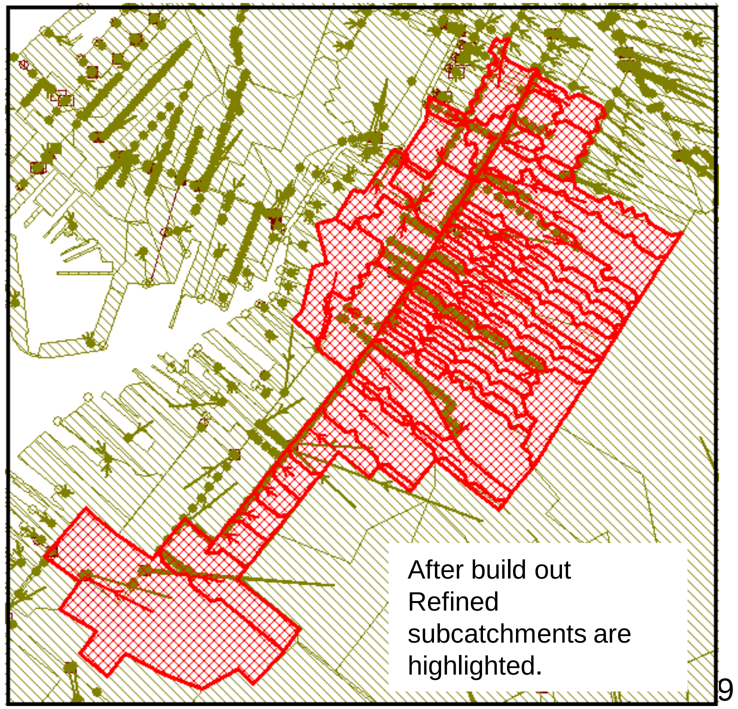


InfoWorks Watershed Model Components

- Started from existing Red Hook model and Coney Island-Owls Head model for the LTCP project
- Combined existing Red Hook model and Coney Island-Owls Head model into one model
- Added more sewer pipes and manholes into the combined model (24” and larger) upstream and downstream of Gowanus tributary areas
- Manhole rim elevations were updated for the study area (assuming the rim elevation is same as the ground elevation).
- Missing inverts were interpolated from available data
- Existing calibration was verified
- Refined subcatchments



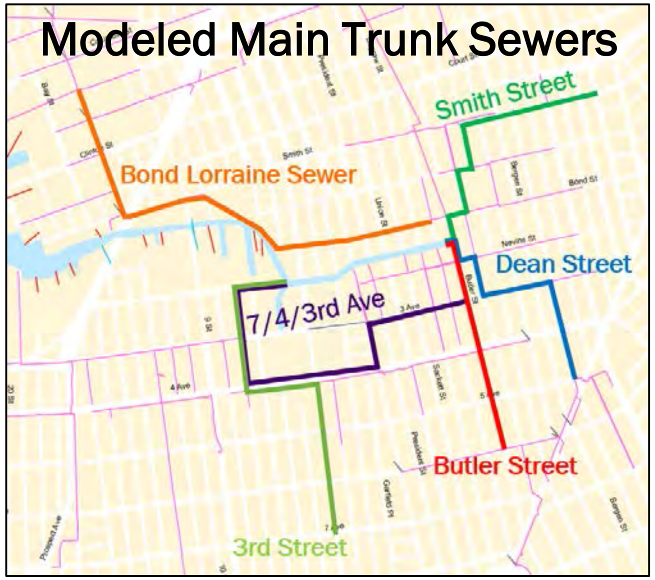
Before build out
Original subcatchments are highlighted

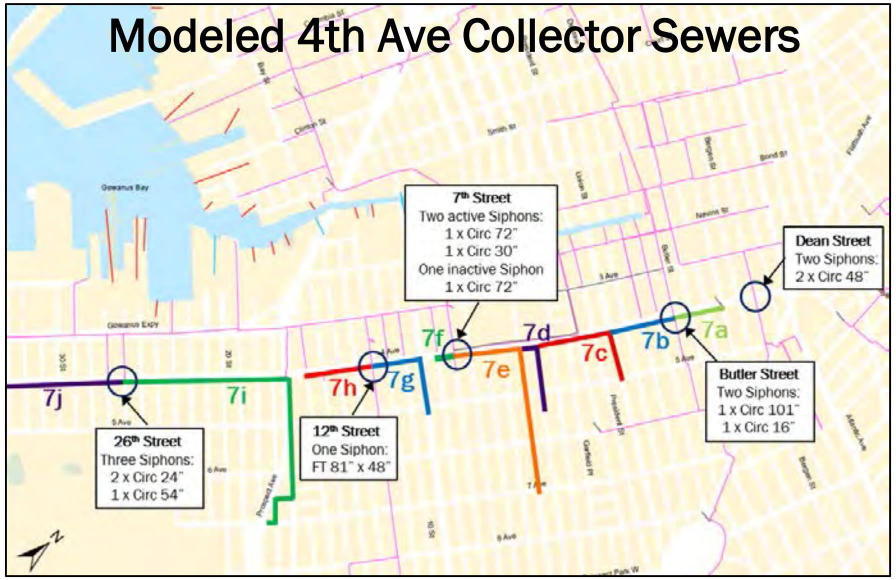


After build out
Refined subcatchments are highlighted.

Trunk Sewers and 4th Avenue Siphons Modeling Summary

NYC Environmental Protection



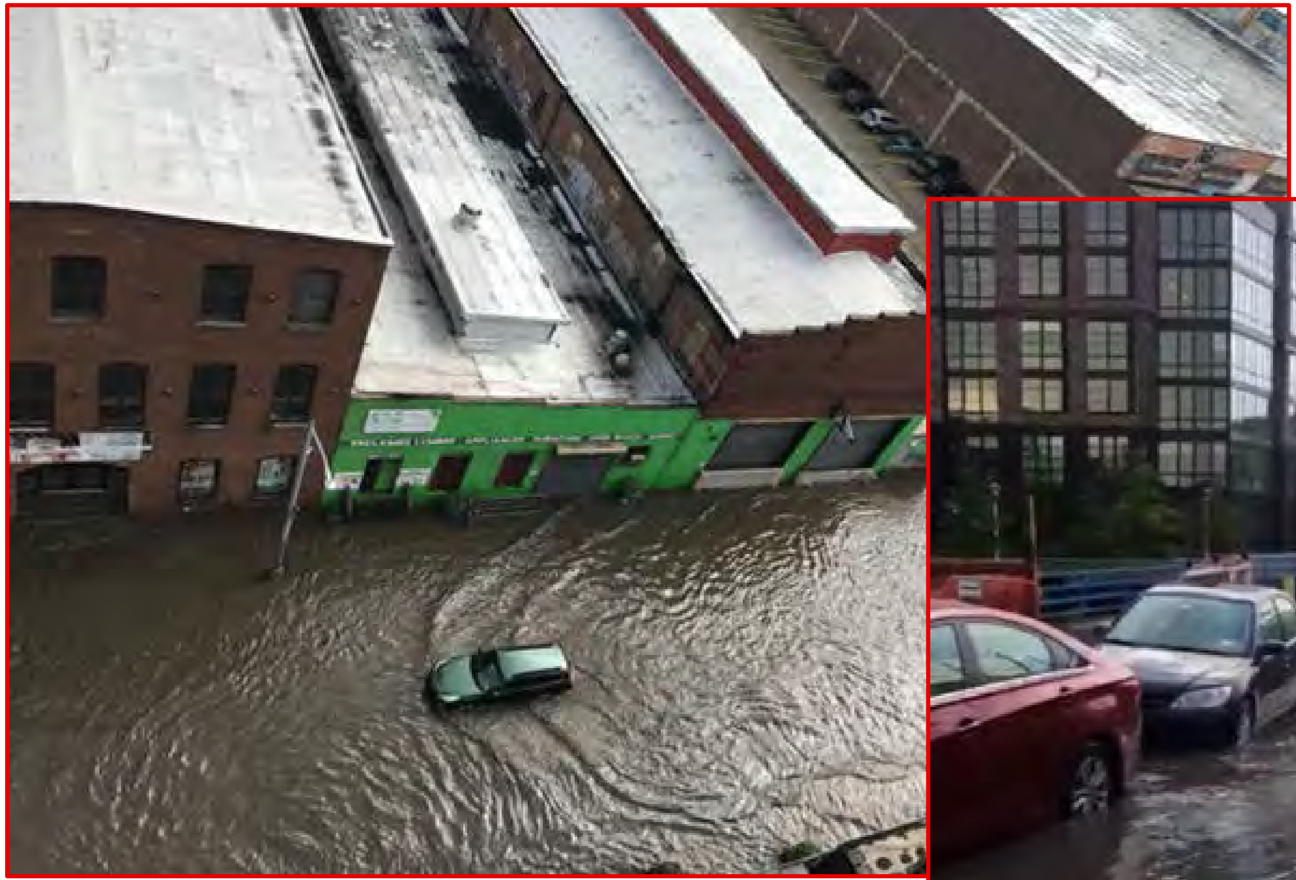


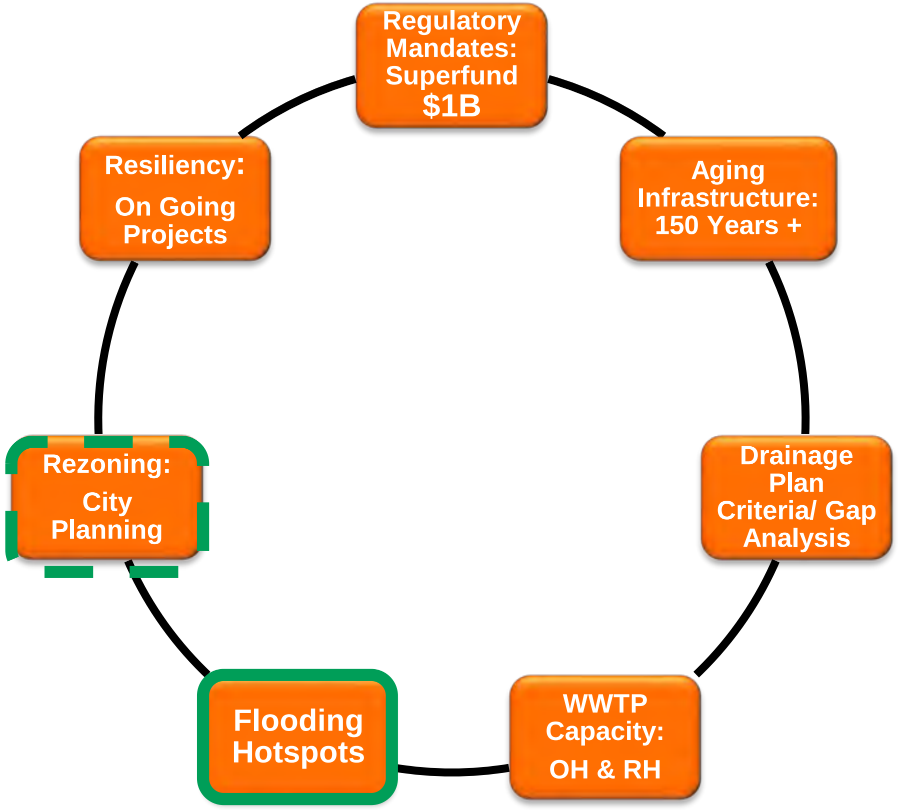
MODELED RAINFALL EVENTS	Rain Duration (hour)	Total Rain Depth (inches)	2 hour Rain Depth (inches)	1 hour Peak (inches)
2-year NOAA 2nd Quartile Rainfall Event	24	3.60	0.73	0.37
5-year NOAA 2nd Quartile Rainfall Event	24	4.70	0.96	0.48
6/14/2008 Storm	5	1.66	1.57	1.36
DEP 5-year Storm	2	1.84	1.84	1.66
8/14/2011 Storm	23	7.80	3.14	2.41
Hurricane Harvey	65	28.28	3.94	2.00

	Smith St	Butler St	Dean St	7/4/3rd Ave	3rd St	Bond Lorraine	Butler St	7th St					12th St		26th St	
			Siphon				Siphon				Siphon		Siphon		Siphon	
Storm Event with 58" SLR	–	–	–	–	–	–	7a	7b	7c	7d	7e	7f	7g	7h	7i	7j
2-year NOAA 2nd Quartile Rainfall Event	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
5-year NOAA 2nd Quartile Rainfall Event	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
6/14/2008 Storm	✓	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓	✓	✓	×
DEP 5-year Storm	×	✓	×	×	×	×	✓	×	×	×	×	×	×	×	×	×
8/14/2011 Storm	✓	✓	×	×	×	×	✓	×	×	×	×	×	×	✓	×	×
Hurricane Harvey	✓	✓	✓	×	×	×	✓	×	×	×	×	×	✓	✓	×	×
			Local Issue at Siphon	Mid Priority Problem		Highest Priority Problem		Highest Priority Problem					Lowest Priority Problem		Mid Priority Problem	

Legend
✓ Not Surcharged
× Surcharged

Issues Affecting Gowanus – Flooding

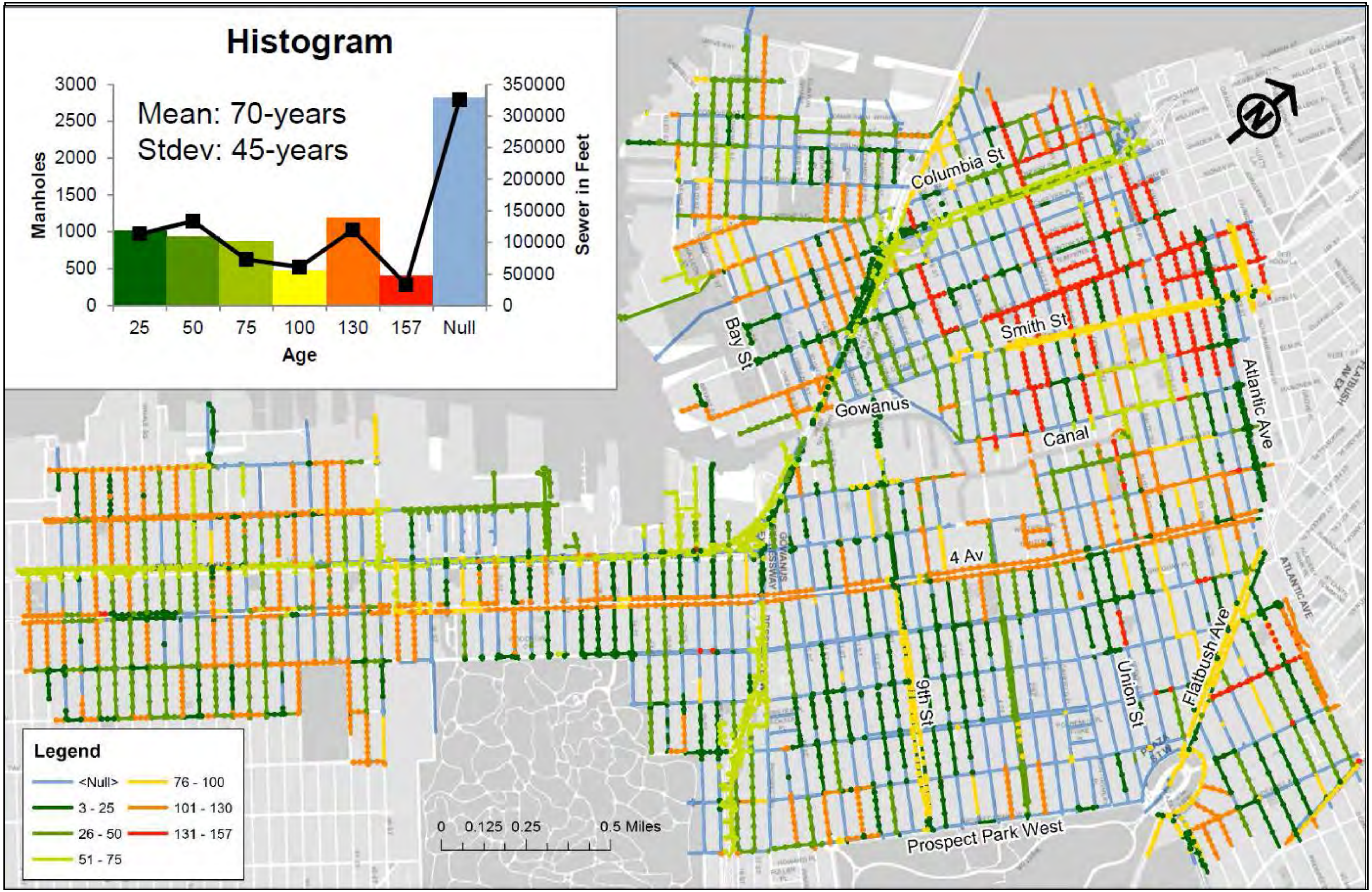




Can be addressed by a tunnel storage system

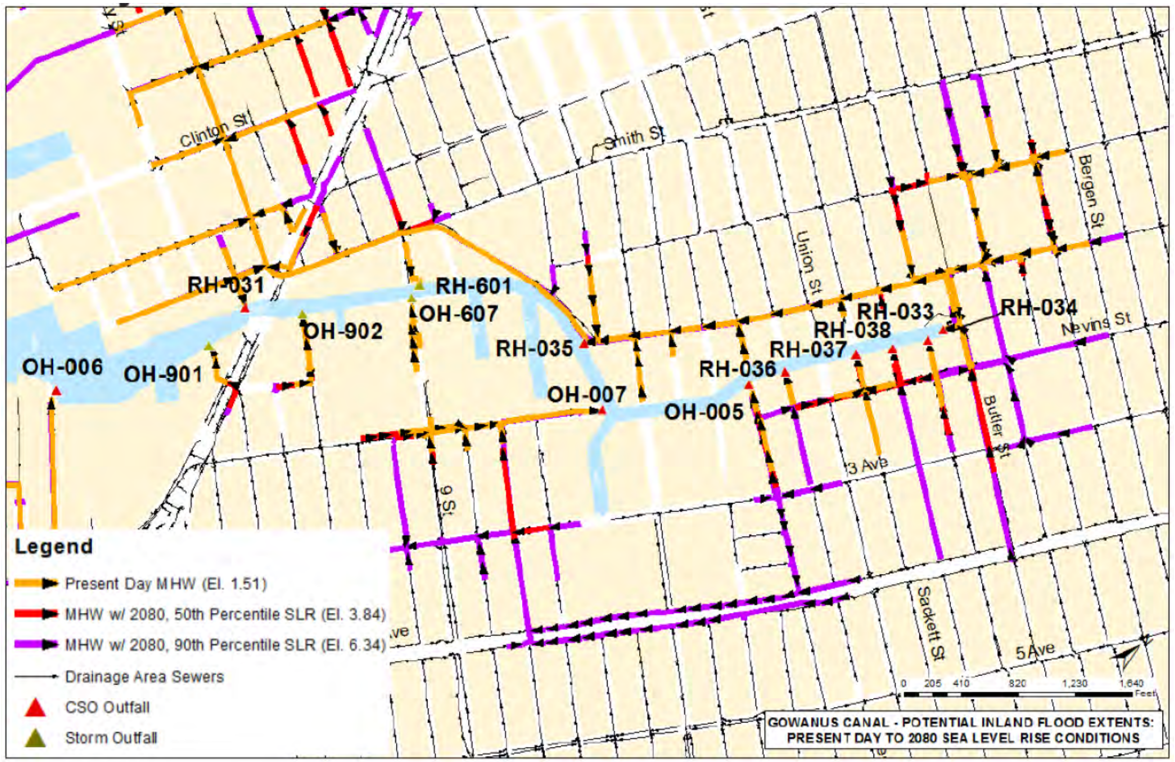
Would be indirectly benefited by a tunnel storage system

Age of Existing Sewers



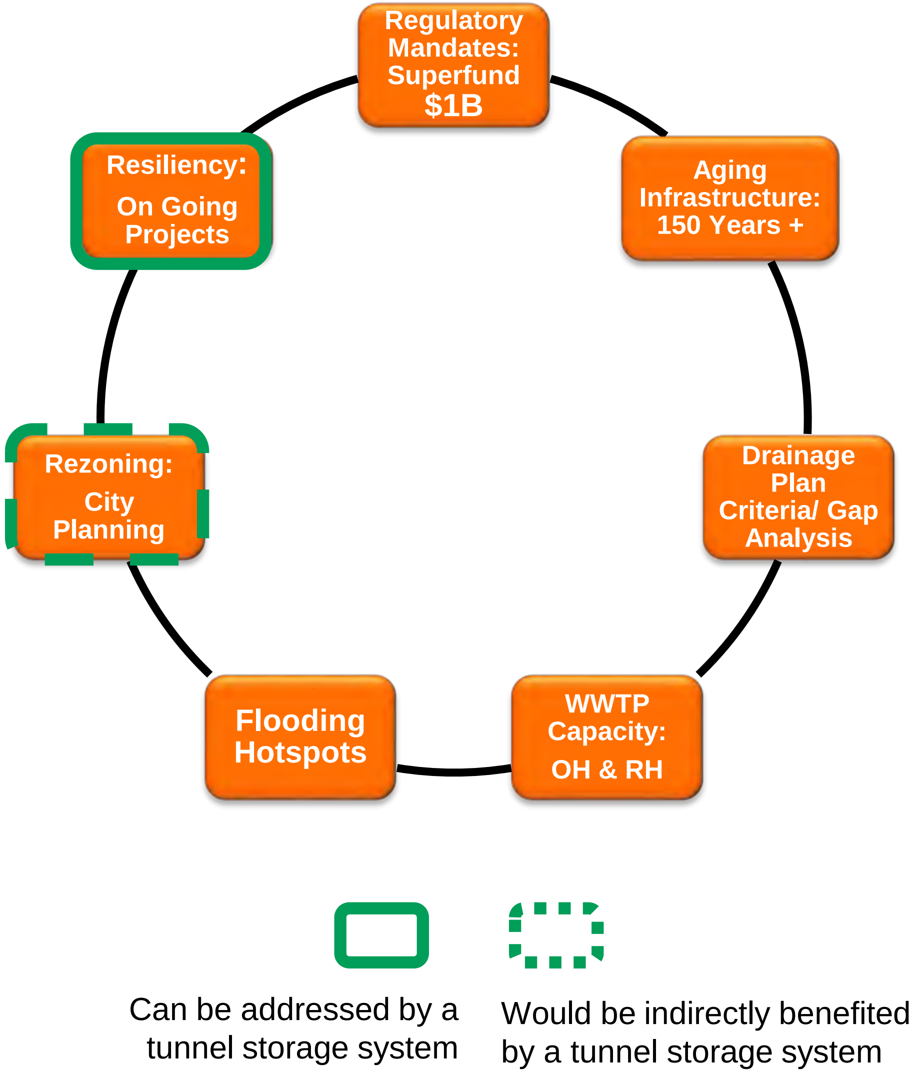
Issues Affecting Gowanus - Resiliency

Sea Level Rise (SLR)



Theoretical impacts of SLR on tidally-influenced sewers in the Gowanus Canal drainage area Under 2080 Sea Level Rise[1]

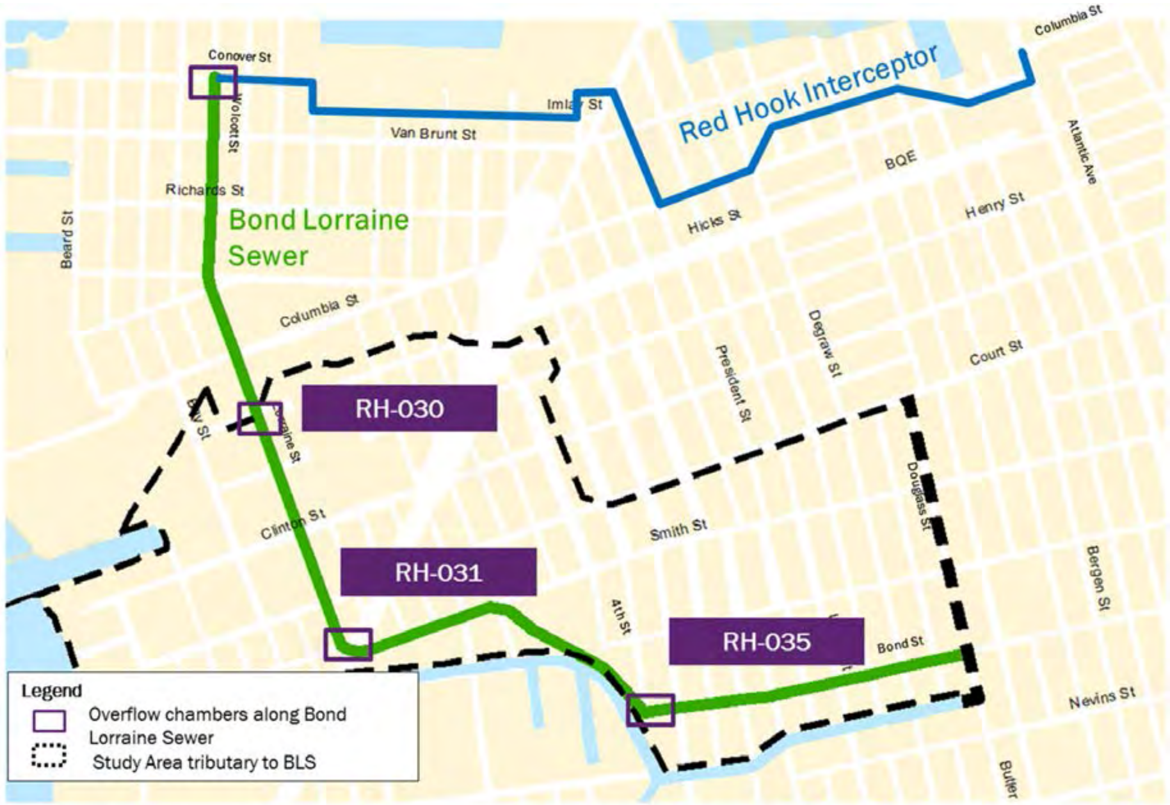
Tidal Scenario	MHW Elevation (BHD)
Present Day MHW	1.01
2080 50th Percentile SLR + MHW (28" SLR)	3.43
2080 90th Percentile SLR + MHW (58" SLR)	5.84

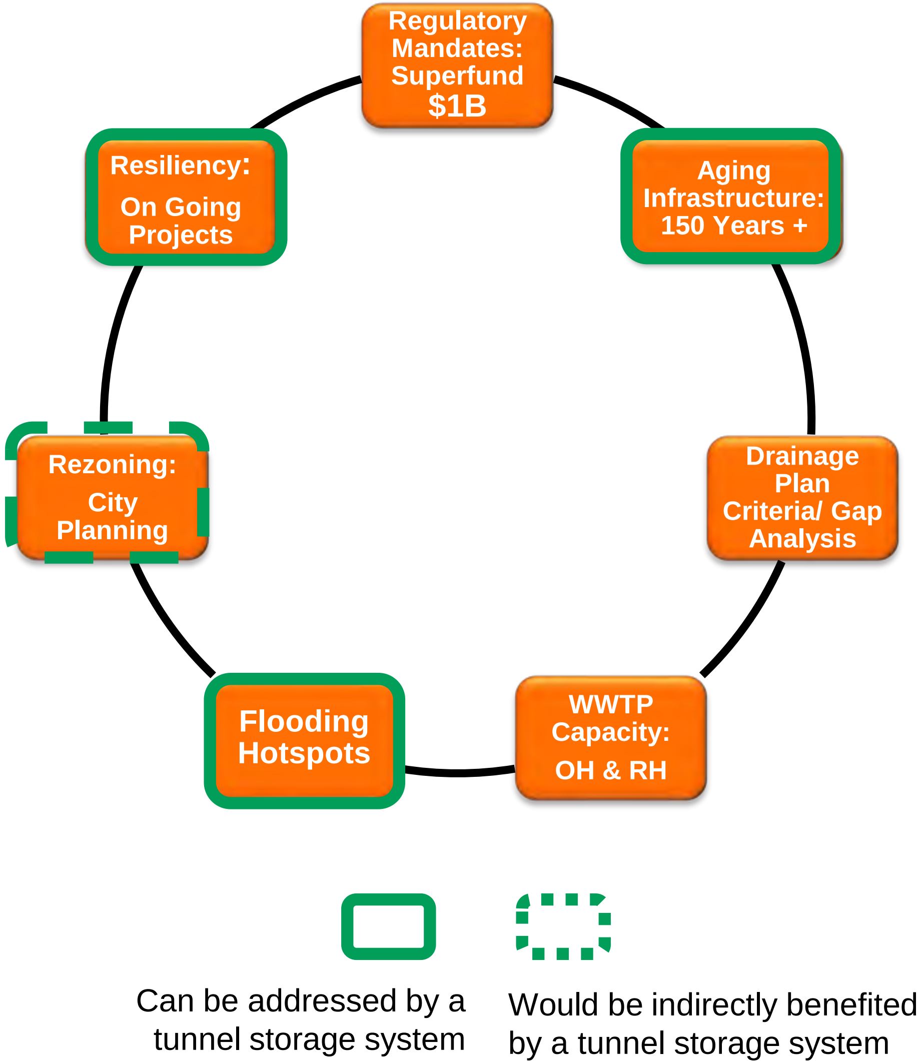


[1] Based on the LTCP team's computer program-driven estimates using NOAA-based astronomical tide data at reference stations, and corrected for local conditions.

Issues Affecting Gowanus - Bond-Lorraine Sewer

- Bond-Lorraine sewer currently 50% full during dry weather (normal capacity is 10% to 20% full)
- Prone to sedimentation and flooding
- Tidally influenced – three regulator structures connect to sewer (making it a pseudo interceptor)
- Connected to the Red Hook Interceptor.





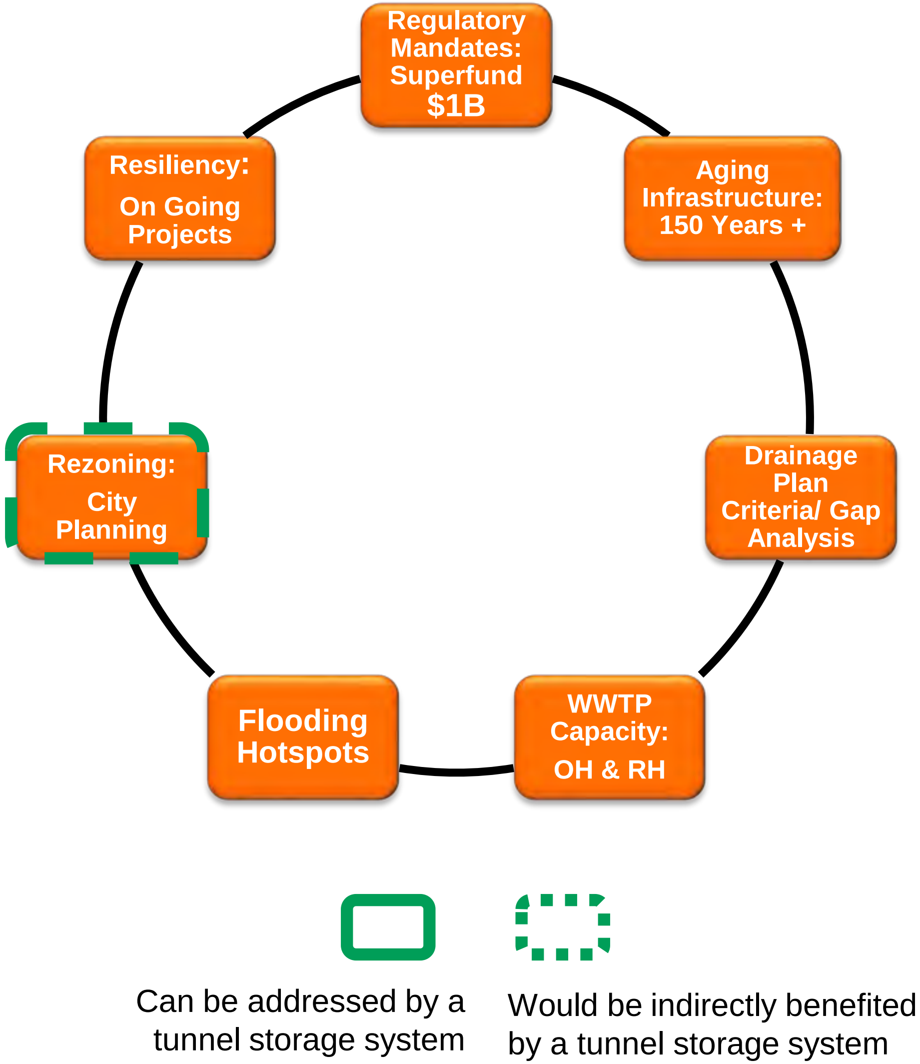
Issues Affecting Gowanus - Growth

Projected Neighborhood Growth / Re-Zoning

- Area ripe for redevelopment currently, As-of-Right
  - 1,941 residential units have been added in last 5 years in Brooklyn Community District 6.
  - Demand for further redevelopment – pending DCP rezoning plan
- Rezoning would allow for addition of about 12 to 13.5 million square feet of development potential – increasing tax base

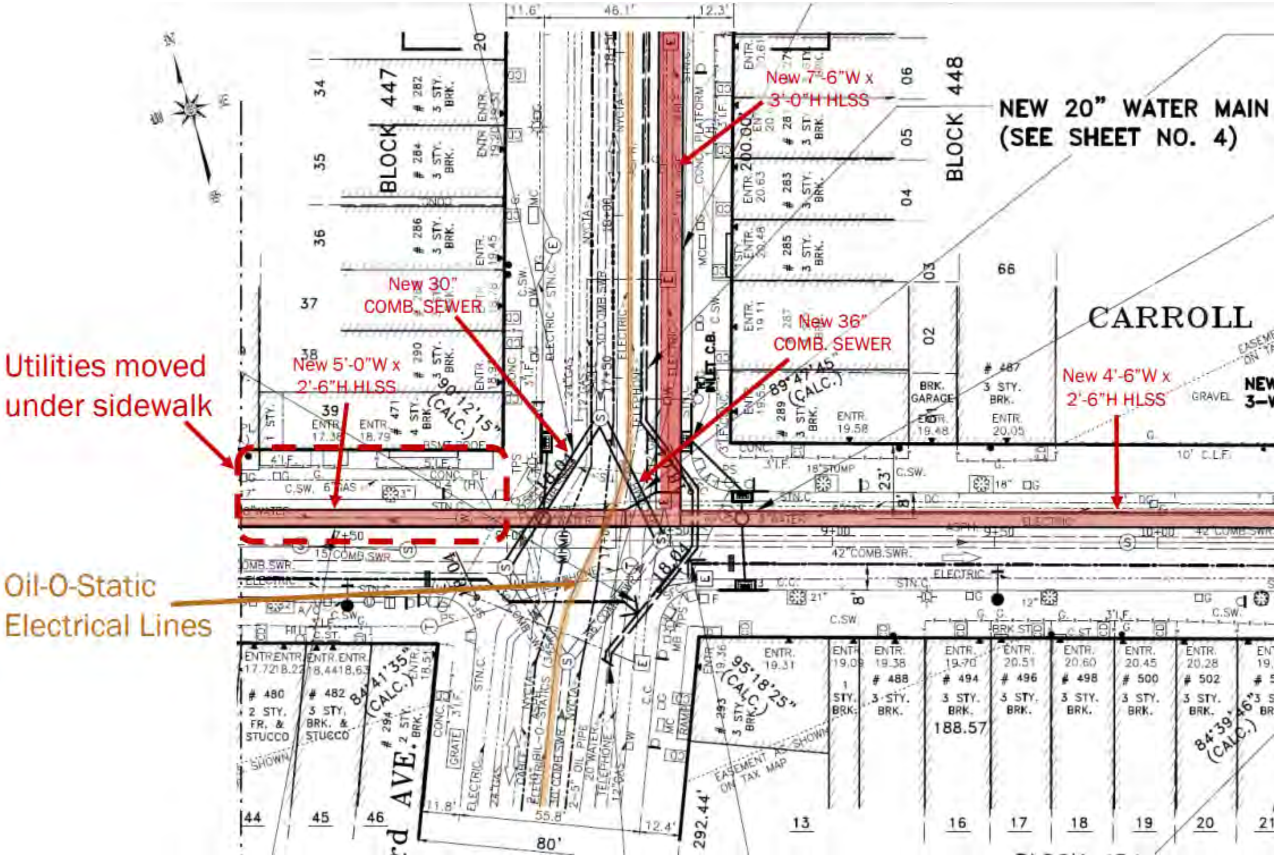
- Most sewers in area are not designed to current design criteria.
- Many areas with the highest likelihood of redevelopment located in areas of known flooding.
- Additional capacity would minimize flooding impacts for areas of new development.

365 Bond Street Lightstone Development

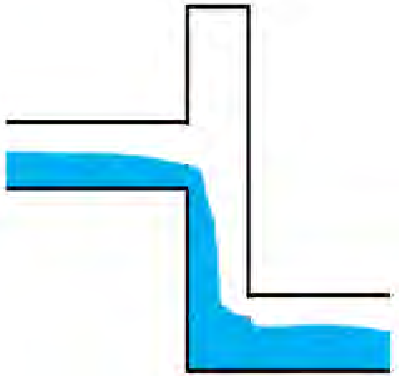


- Conventional sewer construction solutions are not practical and would be cost-prohibitive

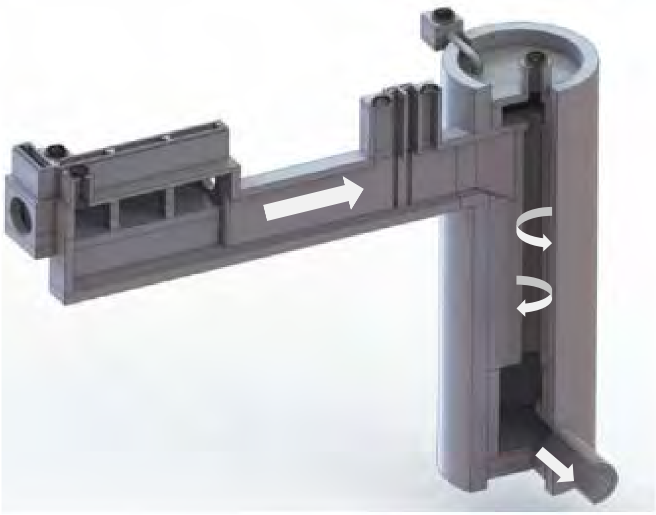
- Tunnel would provide a free discharge outlet and would mostly avoid interference with utilities



High-Level Storm Sewers Construction (Carrol St. & 3rd Ave.)



Free Discharge Concept

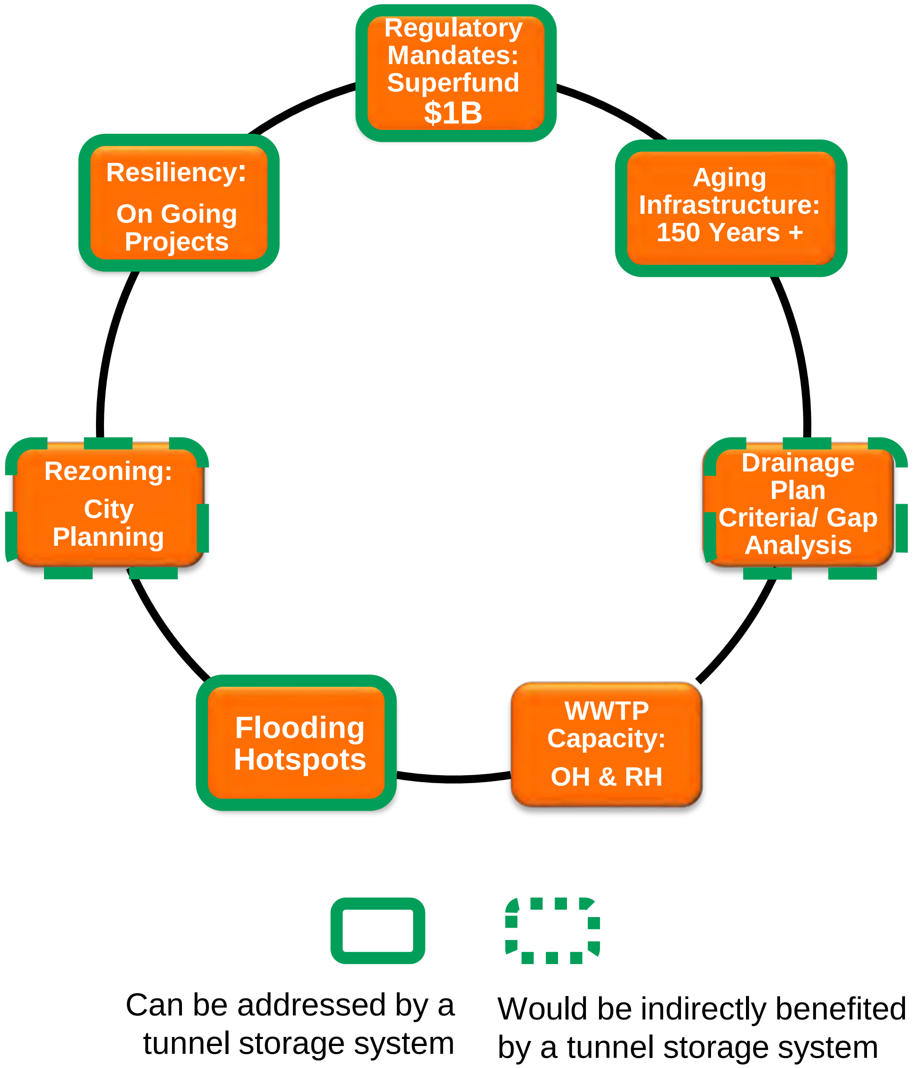


Tunnel Drop Structure

Tunnel Concept

A tunnel concept would provide opportunity to develop a program that will:

- Build on CSO tank facility planning work
- Provide long term neighborhood benefits
- Serve a larger area surrounding the Gowanus Canal
- Address resiliency further into the future
- Provide an outlet for future sewer upgrades/repairs
- Allow multi-phase program implementation
- Advance with the industry trending towards tunnel storage



Example Multi-Phase Tunnel Program

Two-Stage Tunnel Construction Concept; Two Shafts at OH-007; Total Storage Volume 37.3 MG)

Phase 1: $ 1.2 B
Phase 2: $ 0.2 B
Phase 3: $ 0.9 B
Phase 4: $ 0.1 B
Total: $ 2.4 B

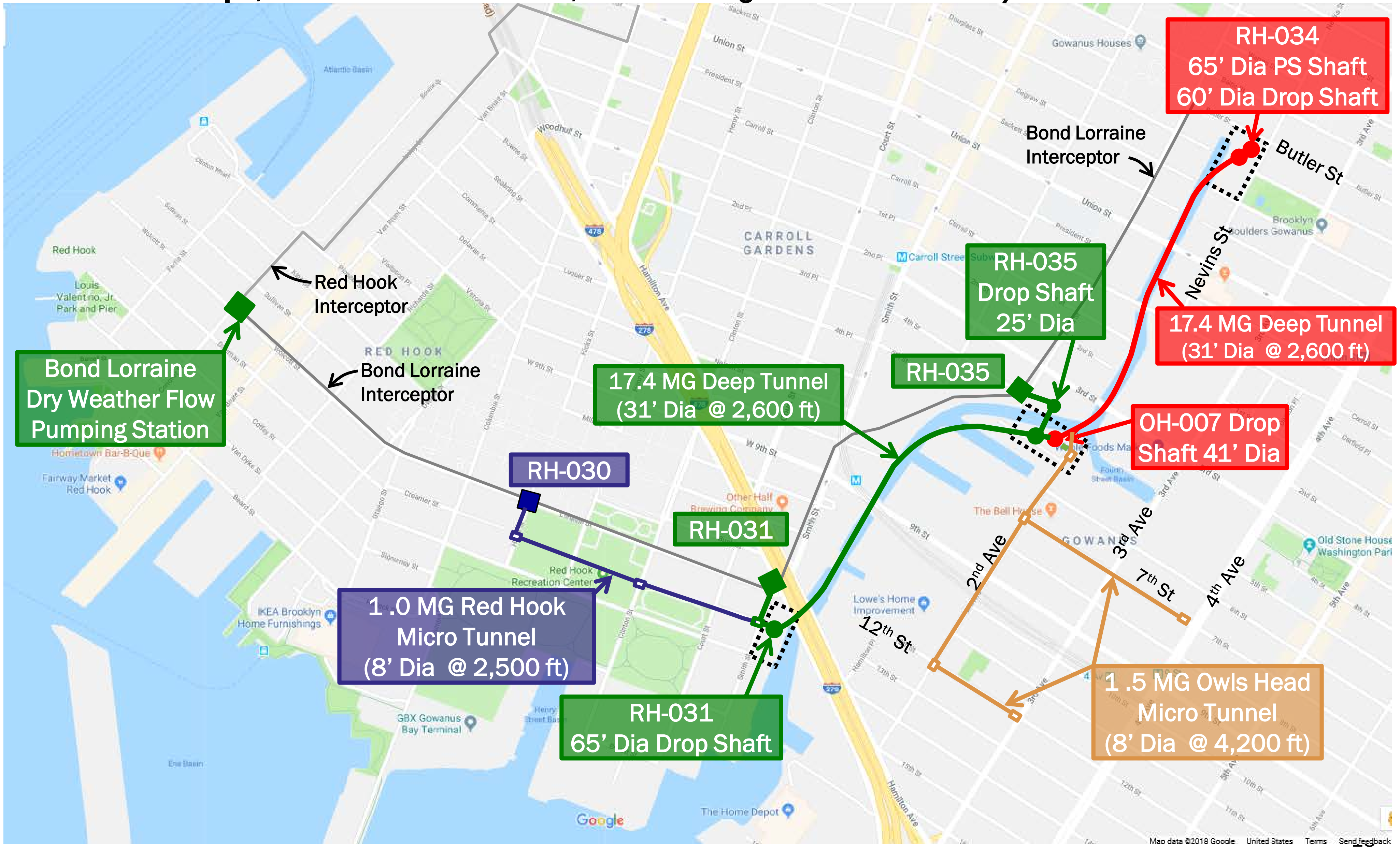
Benefit

ROD Storage

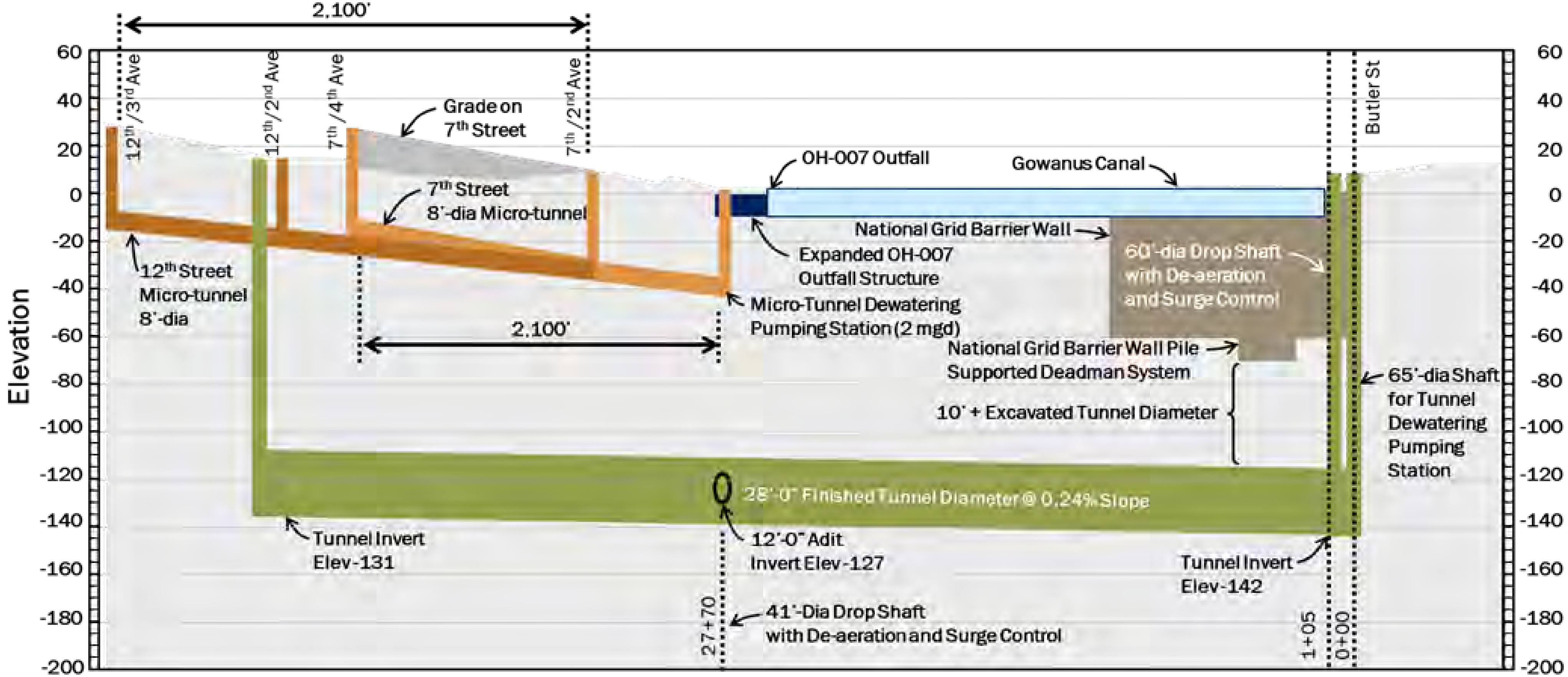
Park Slope Flooding

Bond Lorraine

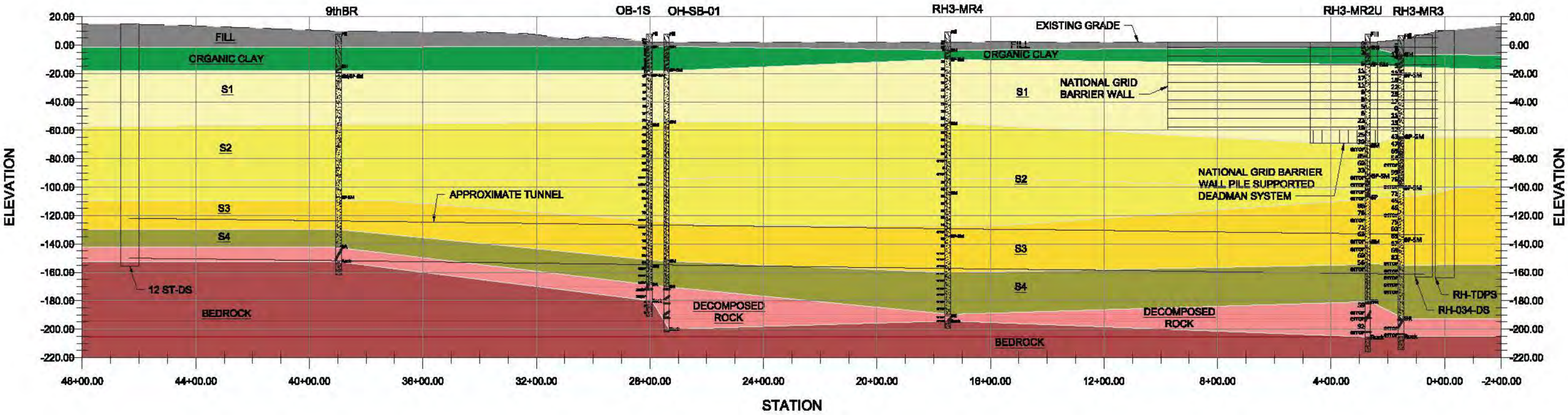
Carroll Gardens Resiliency, Flooding



Conceptual Profile



Geotechnical Conditions Along Gowanus Canal

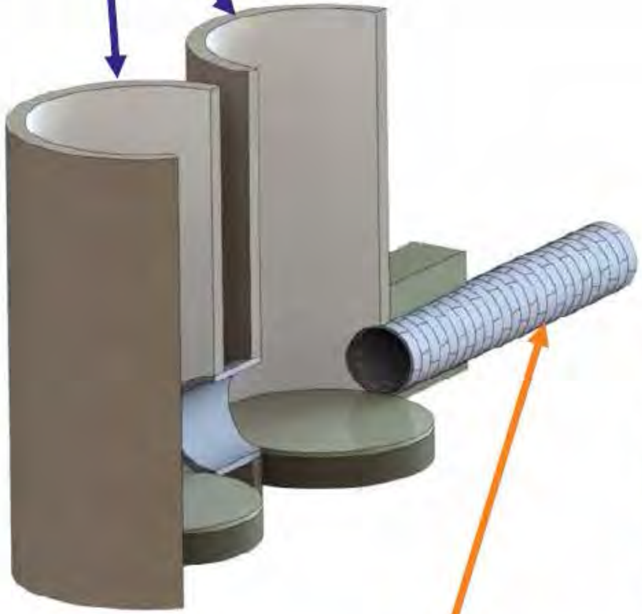


- Tunnel will be in soft ground to minimize depth for pumping and access / maintenance considerations.
- Tunnel is feasible using pressurized face Tunnel Boring Machine (TBM)
- Vertical alignment constraints are NAPL barrier wall and rock.
- Horizontal alignment constraints are the canal and public space

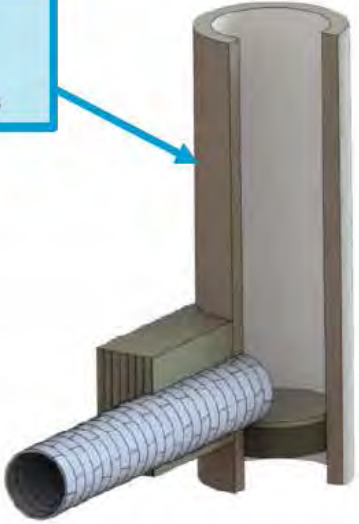
Tunneling Approach

Pump Station and Mining Shafts
- Binocular or Snowman configuration allows simultaneous tunneling and pump station construction.
- Slurry wall SOE

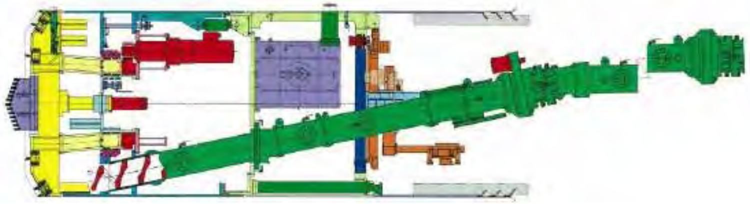
DC Water (Washington, DC)



Terminal Shaft
- TBM removal
- Drop shaft and other facilities



Tunnel Excavated with TBM
- Earth Pressure Balance (EPB) or Slurry TBM
- Advance rates range from 30 to 50 ft/day
- Turning radius 800' minimum
- One-pass Segmental Liner



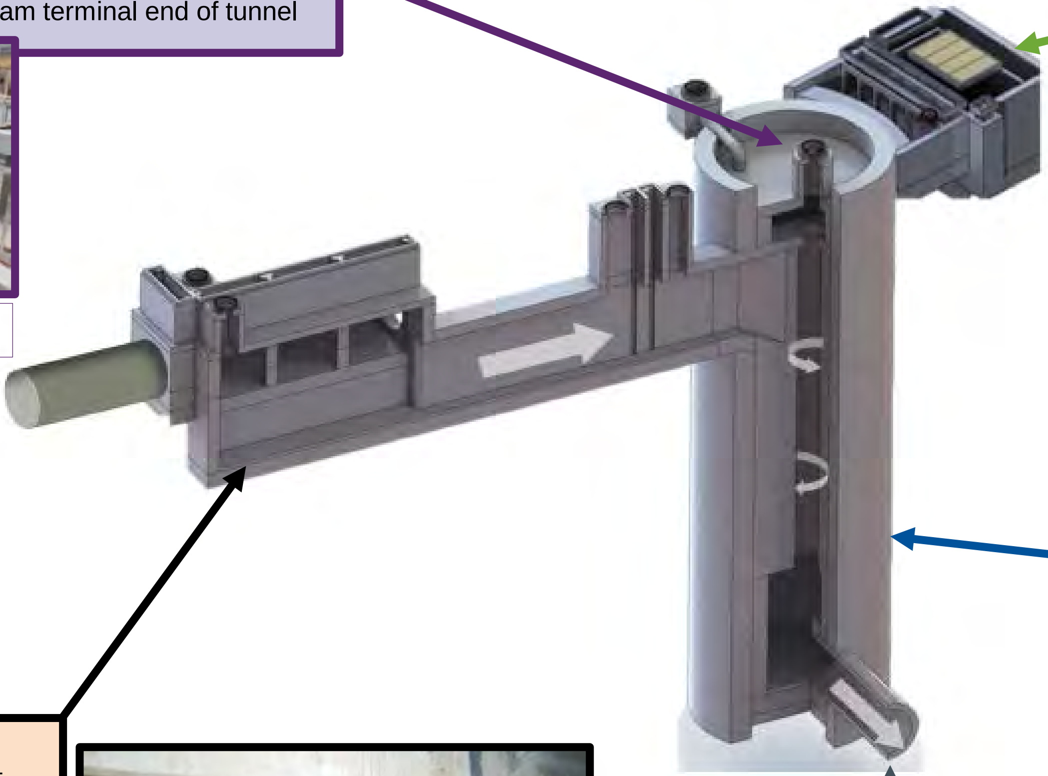
Gowanus Tunnel Components

Environmental Protection

Venting

- Passive ventilation at all drop shafts
- Gravity dampers to prevent convective air cycling
- Active ventilation fans at upstream terminal end of tunnel

DC Water (Washington, DC)



Odor Control

- Limit flows to wet weather only
- Radial flow GAC units
- Larger venting & odor control superstructure at the upstream terminal shaft
- Smaller odor control facilities included at pump station & other drop shafts

DC Water (Washington, DC)

Drop Shaft

- Tangential vortex drop shafts (41-65' ID)
- Drop shafts at terminal ends of the tunnel mitigate hydraulic transients & geysers
- Removable covers allow equipment & personnel access to tunnel

DC Water (Washington, DC)

Diversion Structure

- Maximize residuals management near the surface
  - 3-4" trash racks for floatables/large debris
  - Sumps for large debris & grit
- Side overflow weirs & sumps divert collection system to tunnel
- Residuals removal & cleanout required
- Include actuated gates prevent tunnel overfilling

DC Water (Washington, DC)

Tunnel

- Tunnel slope (approx. 0.2%) provides self-cleaning velocity
- Alignment stays within ROWs (Gowanus Canal & 2nd Ave) to limit easements & property acquisition
- Turning radius limited to 800'

Gowanus Tunnel Components

NYC Environmental Protection

Pumps
- Use solids handling pumps w/ n+1+1 redundancy
  - 6 mgd submersible pumps
  - Use fewer duty pumps to increase pump size & solids passage capability
- Trench-style wetwell
- Include gates upstream of PS to avoid grit settling around pumps
- Single stage pumping is desired, but will depend on tunnel depth

Grit Management
- Include sump upstream of bar screen
- Clamshell bucket needed to remove material
- Keep grit in suspension so it can be pumped out
- Use grit cyclones to de-grit tunnel dewatering flows prior to discharge
- Locate gates upstream of PS to prevent grit from settling on pump suction

Pump Station
- Dry-pit submersible PS configuration
- Provides enhanced access to deep pumps
- Superstructure houses pumping, grit removal, screening, odor control, emergency power, HVAC, electrical and control equipment
- Crane/hoist and openings included to raise/lower equipment

Screens
- Mechanical bar rake upstream of dewatering PS to capture floatables & protect pumps (1.5+ inch spacing)
- Optimize bar spacing to provide required protection for pumps and avoid blinding
- Design facility to be un-manned and automate screens to send floatables directly to a dumpster

Brightwater IPS (Seattle, WA)

Narragansett Bay (Providence, RI)

Kailua TIPS (Kailua, HI)

MWRD Calumet PS (Chicago, IL)

Shaft Construction by Slurry Wall

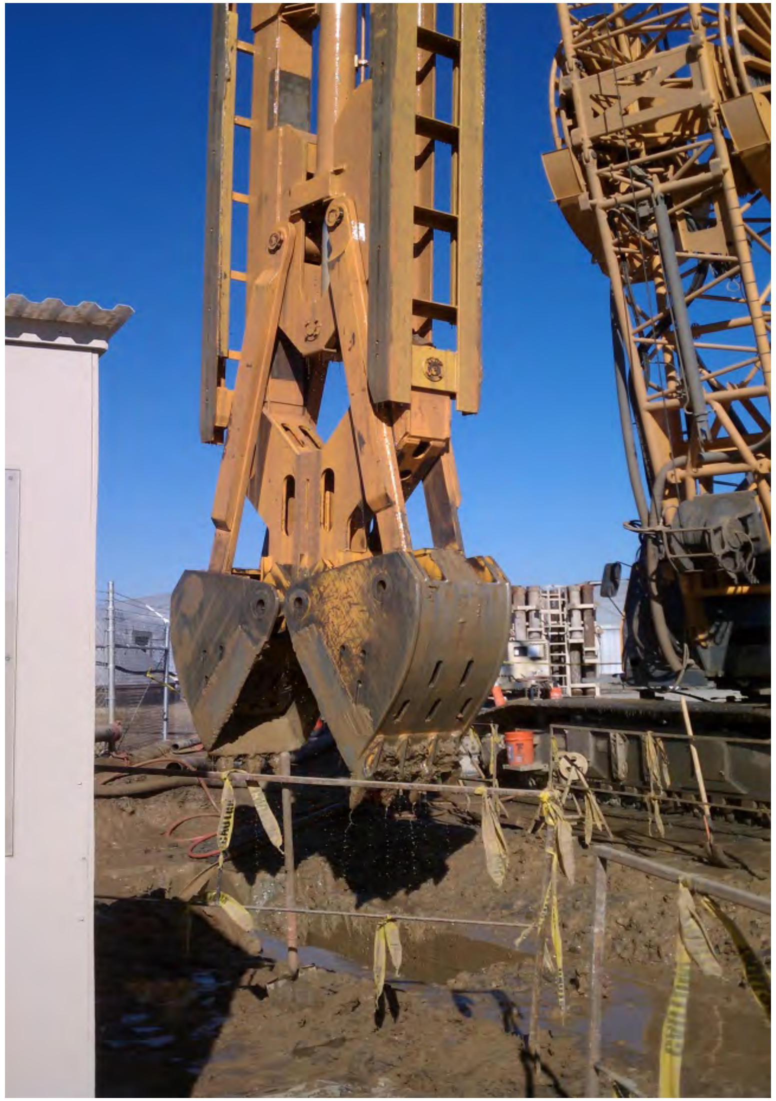
- All shafts constructed using Slurry Wall or Secant Piles Support of Excavation (SOE) systems.
- All shafts are constructed in the wet with a tremie slab to control groundwater.
- All shafts have a Cast-in-place liner installed.
- All drop shafts have internal hydraulic structures, exception:
  - RH-TDPS shaft only has a CIP liner but no internal structures or pumping station facilities.
- TBM launch/removal diameter is a minimum 60-foot ID with CIP liner/collar installed
- Break-ins/outs require jet grout block and collar seal
- Crane Mounted “Excavator” cut’s a trench/wall
  - Clam Bucket at first;
  - Hydromill after depth;
- Slurry (bentonite and water) supports the trench;
- Slurry is “cleaned” and steel is placed in trench;
- Trench is filled with concrete
  - Tremie Method (bottom up);
  - Slurry pumped off for re-use

Slurry Wall Equipment

DC Water
Blue Plains pump shaft

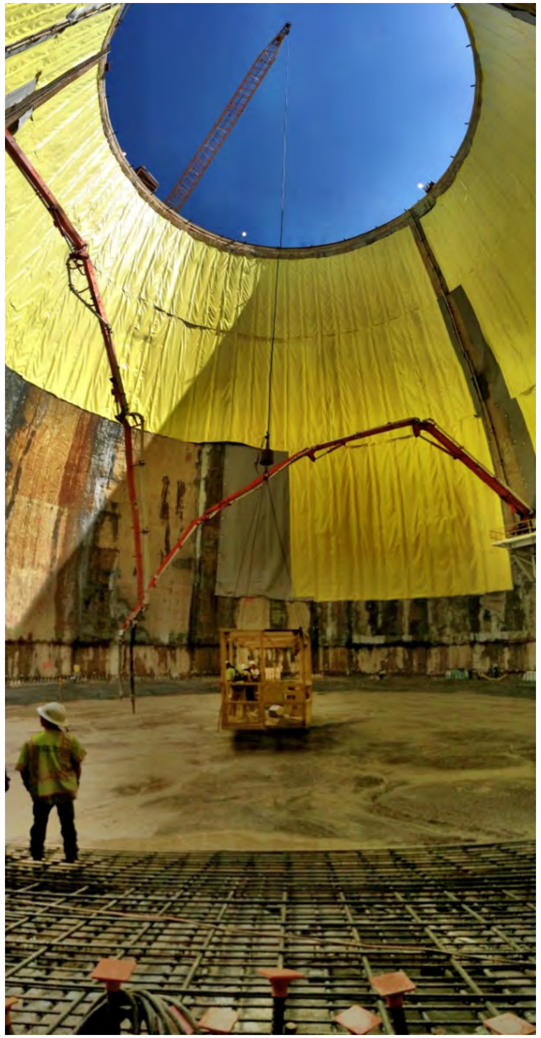
DC Water
Blue Plains pump shaft

Slurry Panel Excavation



Slurry Wall Reinforcing Steel

Completed Excavations

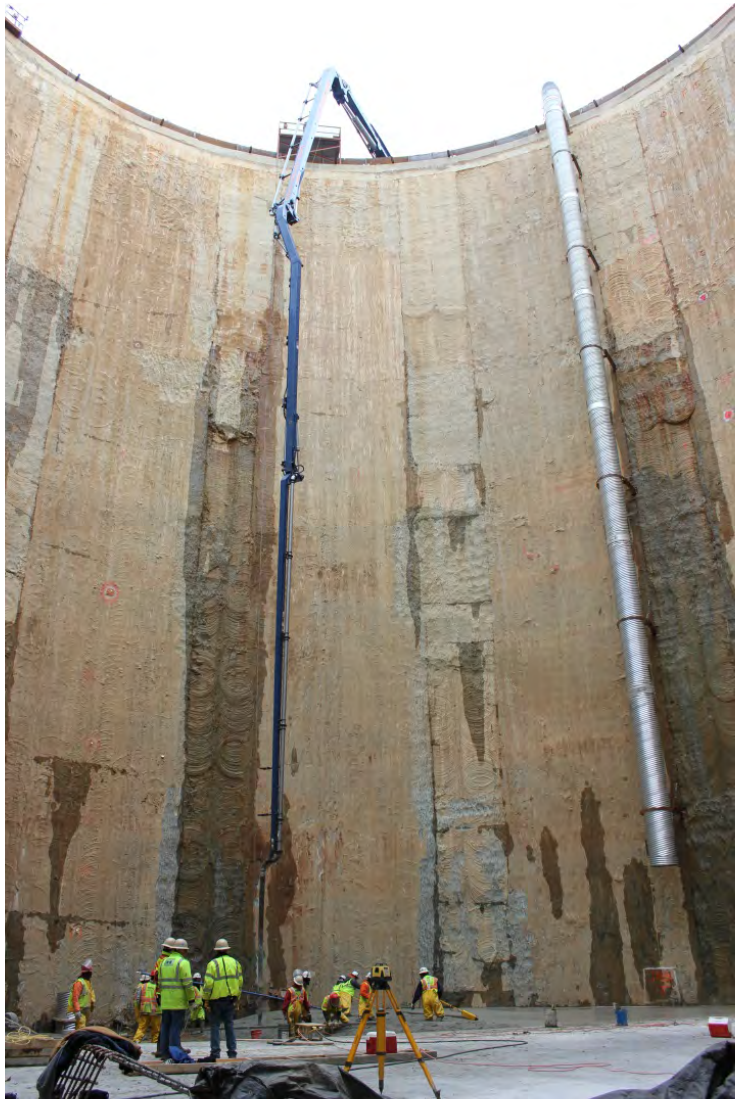


DC Water
Blue Plains pump shaft

DC Water
Polar Point Shaft

DC Water
Blue Plains Screening Shaft

Completed Excavations



DC Water
Blue Plains pump shaft

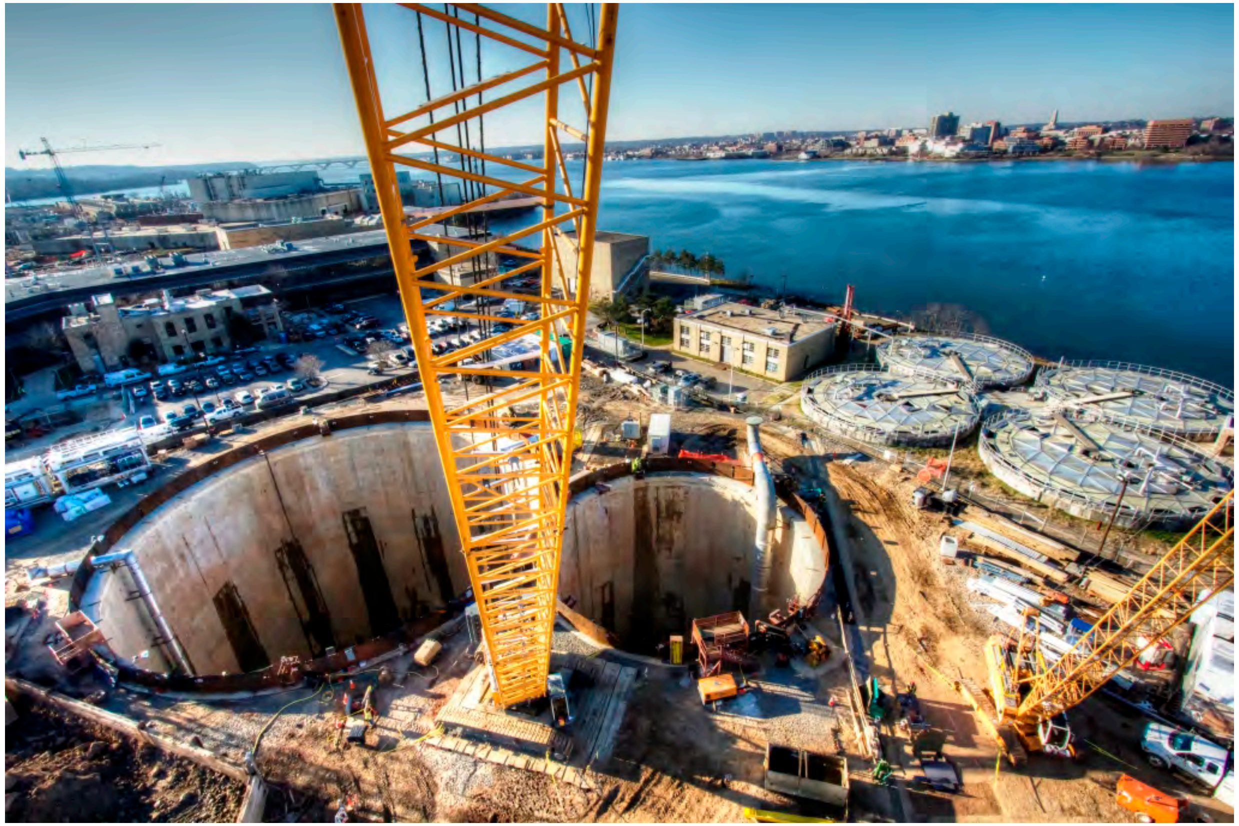
DC Water
Blue Plains Screening Shaft

Completed Shaft

King County WA
Brightwater Pump and
Screening Shafts

DC Water Binocular – Two separate shafts

DC Water
Blue Plains Screening and
Pump Shafts

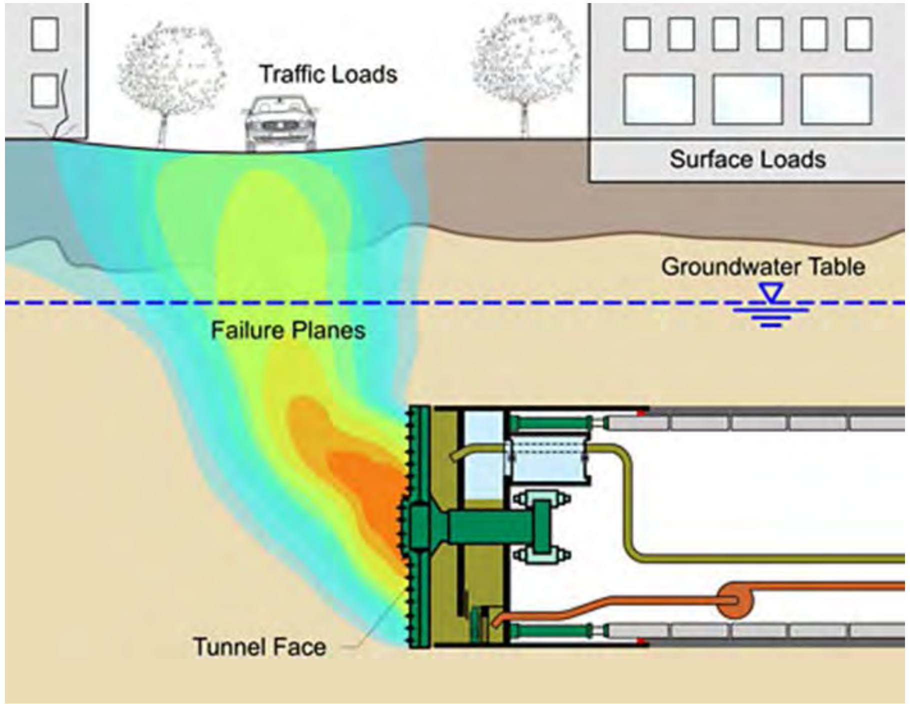


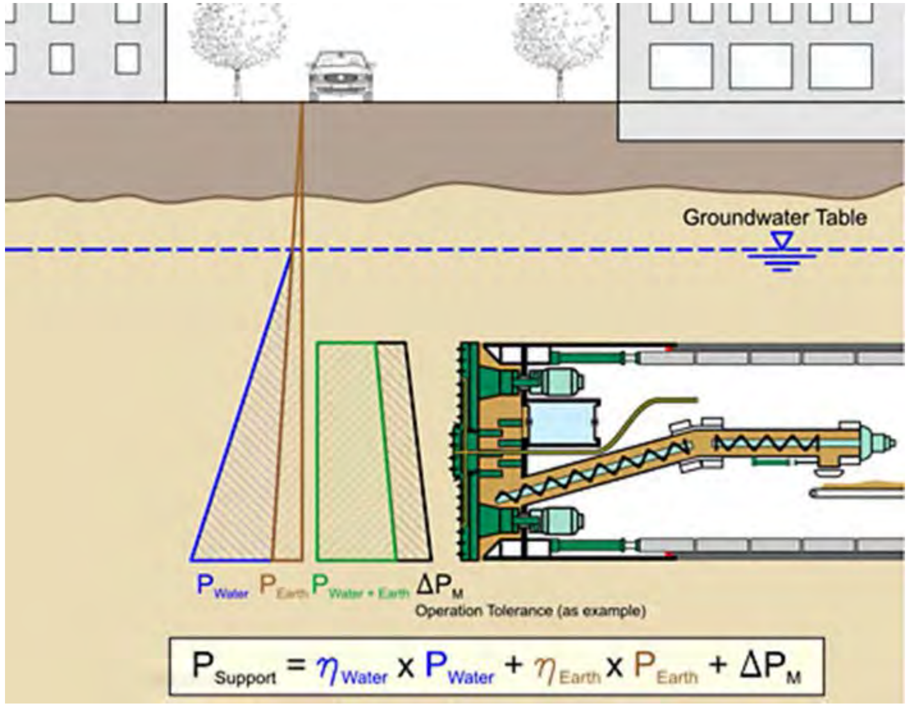
DC Water
Blue Plains Screening and
Pump Shaft

Pressurized Face Tunnel Boring Machines (TBM)

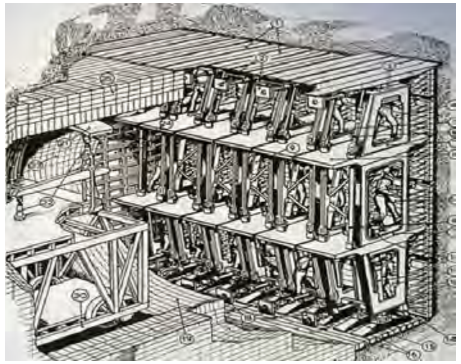
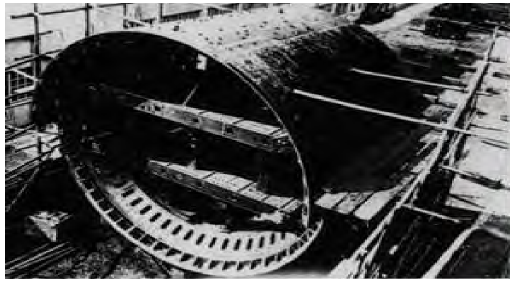
A shield machine is designed to bore a tunnel safely and economically while supporting the load imposed by the surrounding ground and ensuring cutting face stability.

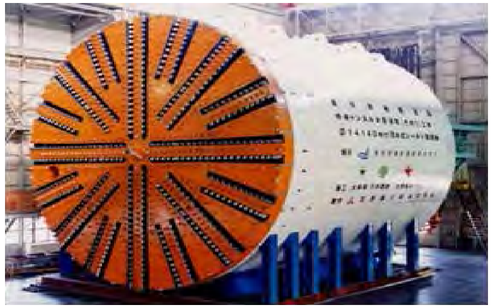
Face Support Pressure vs Induced Settlement in Soft Ground Tunneling

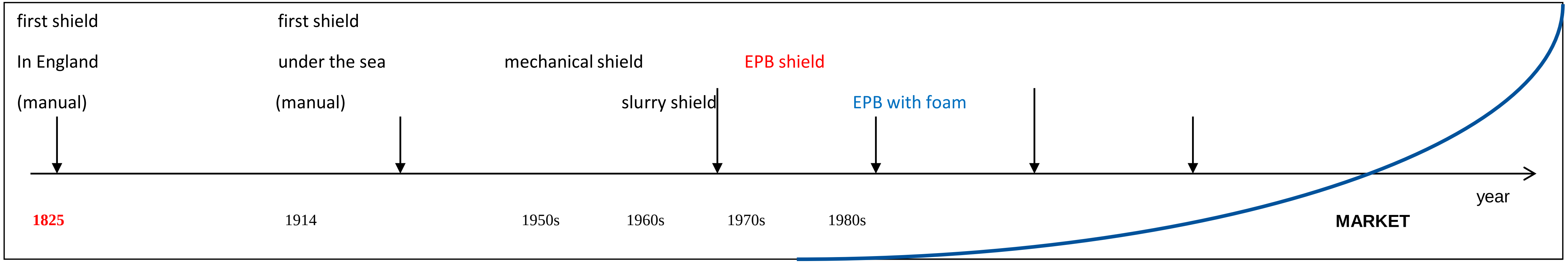




Operating pressures for pressurized TBMs to be defined:
▪ Minimum face pressure, Slurry or EPB mode
▪ Maximum face pressure, Slurry or EPB mode
▪ Compressed air pressure for intervention, chamber partially empty
▪ Compressed air pressure for intervention, chamber completely empty
▪ Injection pressure around TBM skin (typically EPB TBMs only)
▪ Minimum tail void grouting pressure Maximum tail void grouting pressure

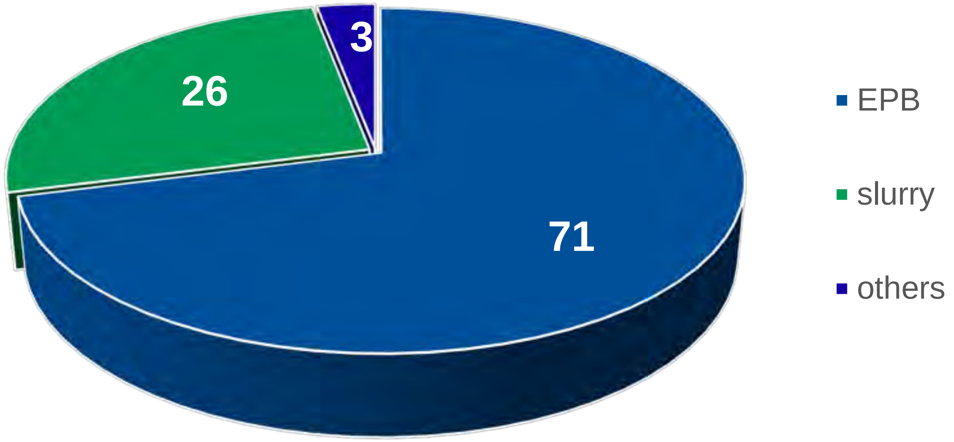







first shield
In England
(manual)
first shield
under the sea
(manual)
mechanical shield
slurry shield
EPB shield
EPB with foam
year
1825
1914
1950s
1960s
1970s
1980s
MARKET

Pressurized Face Tunnel Boring Machines (TBM)

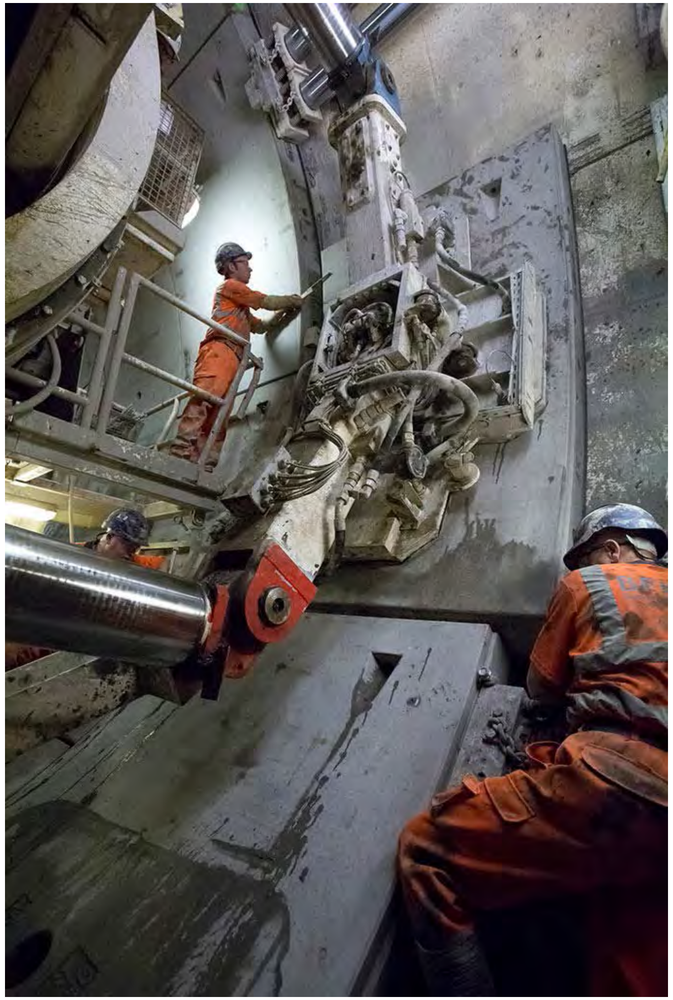
- Major Improvements in Soft Ground Tunneling:
  - Excavation, Lining, and Backfill of Lining all in one continuous operation
  - The TBM is an underground Factory
  - No longer can anyone "see" the face
- There are two main technologies:
  - Earth Pressure Balance = EPB
  - Slurry Pressure Balance = SPB



Segmental lining is the support system for shield TBM excavated tunnels. Pre-cast concrete segments are assembled inside the shield, to form a ring. The segmental ring becomes the support structure of the tunnel.

❖ Advantages

- Curing and Quality of the concrete can be easily tracked and tested in the segment factory.
- Ring erection is done by the TBM, in short time (20~40 min per ring). Rings are positioned with high precision in the shield.
- When leaving the TBM shield, the segmental ring is pre-stressed by the grouting.
- The segmental ring can take the final loads. No hardening time is necessary. The ground is stabilized instantly by the ring and grouting.
- Segmental rings are usually under tangential compression due to tunnel convergence.



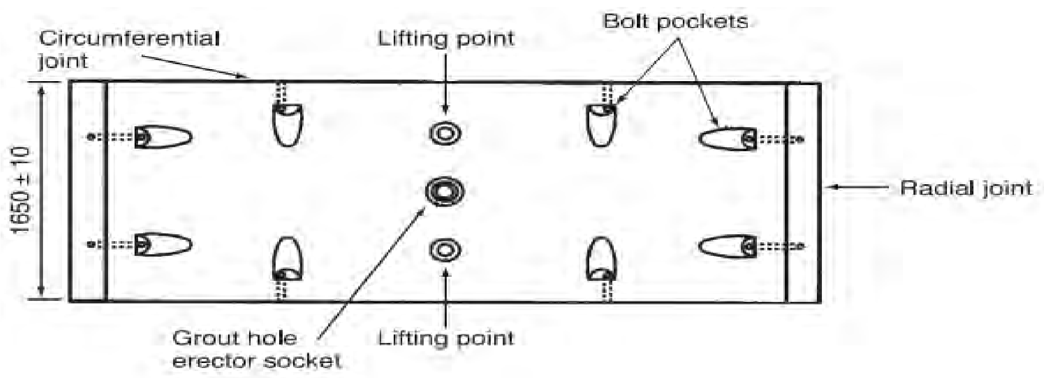
DC Water Blue Plains Tunnel
Segmental Liner used as final liner

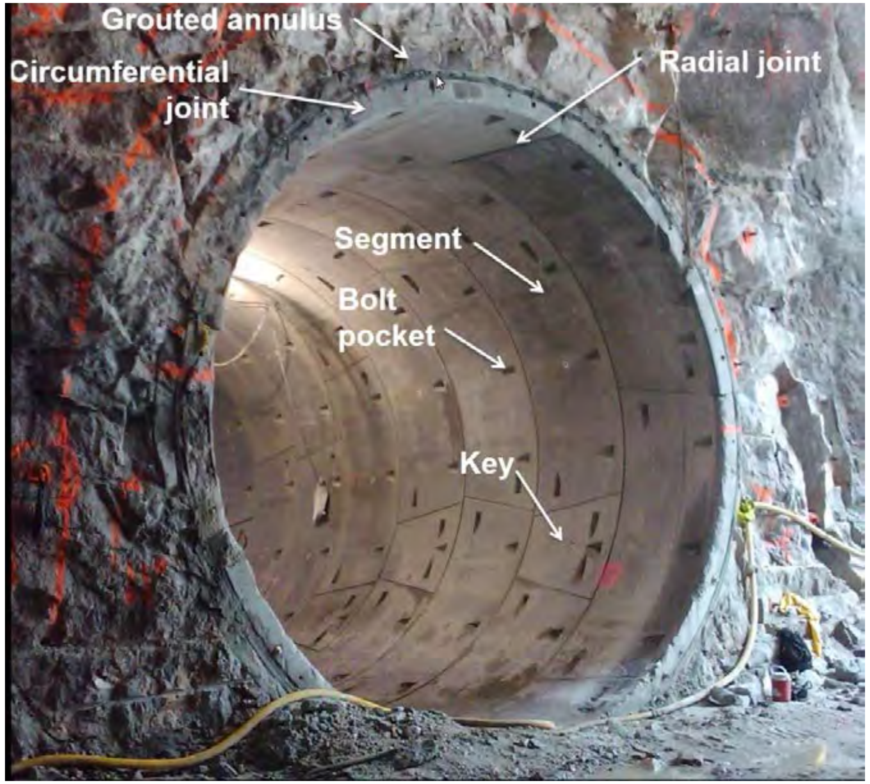
References

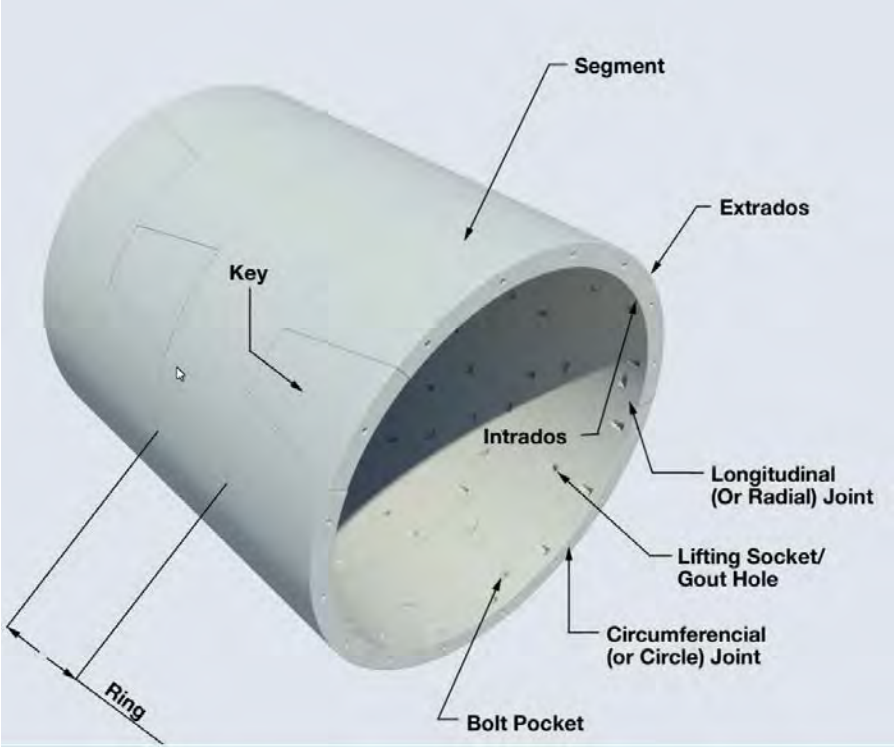
- The British Tunneling Society and The Institution of Civil Engineers, *Tunnel lining design guide*, Thomas Telford Publishing, ISBN: 0 7277 2986 1
- ITA-Working Group 2 Research. *Guidelines for Design of Shield Tunnel Lining*, 2000
- ITA-Working Group 2 Research. *Twenty Years of FRC Tunnel Segments Practice: Lessons Learnt and Proposed Design Principles*. ITA Report N.16 / April 2016 ISBN: 978-2-970 1013-5-2
- AFTES Guidelines. *The design, sizing and construction of precast concrete segments installed at the rear of a tunnel boring machine (TBM)*. GT18R1A1, 2005 - HS1.
- DAUB ITA-AITES German Tunneling Committee. *Recommendations for the design, production and installation of segmental rings.*

Lining System

Segmental lining includes the following structures and parts







Construction Staging

DC Water
Blue Plains pump shaft

DC Water
Blue Plains Screening and Pump shafts

Resiliency Benefits Tank vs Tunnel

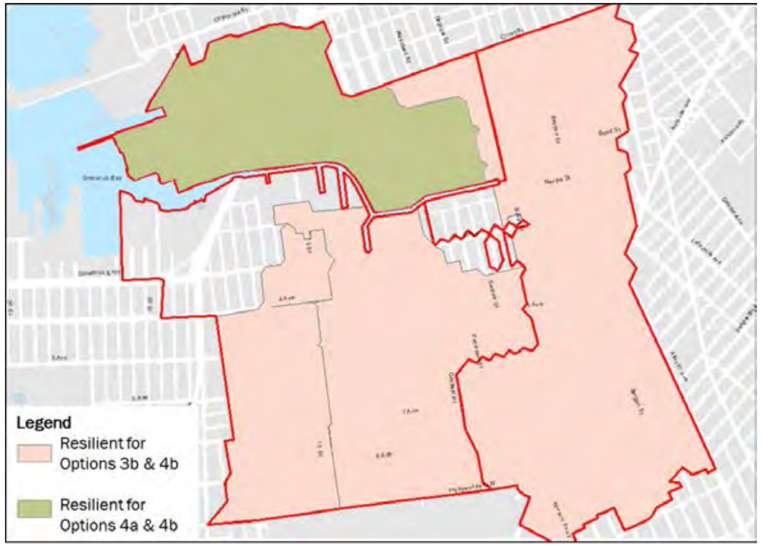
Legend:
Tidally Influenced Sewers for 5-Year DEP Storm at MHW + 58" SLR

Existing System

Tunnel with Flooding & Resiliency Benefits (Option 3b)

Tunnel with Flooding & Resiliency Benefits and Bond Lorraine Connection (Option 4b)

Option 3b and 4b tunnels fully capture flows from the 5-year DEP storm, it effectively makes the OH-007 and RH-034 outfalls and their tributary sewers "resilient" against sea level rise since no CSO would be discharged to the canal under this rainfall event. Option 4b also provides resiliency for the RH-030, RH-031, and RH-035 outfalls along the Bond Lorraine sewer. The resiliency benefit would be seen for any storm event up until the point at which the tunnel is filled.



Resiliency Benefits Existing vs Tunnel

Legend:

Tidally Influenced Sewers for 5-Year DEP Storm at MHW + 58" SLR

Existing System

Tunnel with Flood/ Surcharge Reduction and Resilience Benefits plus Bond Lorraine Sewer Relief (Option 4b)

- The sea level rise resiliency benefit is for the 5-year DEP storm event at MHW + 58" of sea level rise. "Resiliency" indicates that the tunnel system provides a 5-year DEP outlet for the sewershed upstream of the tunnel connections.
- Making outfalls OH-007 and RH-034 and their tributary sewers, and the outfalls associated with the Bond Lorraine sewer (RH-030, RH-031, and RH-035) "resilient" against sea level rise since no CSOs from these outfalls would be discharged to the canal under this rainfall event or up until the point at which the storage system is filled.

Flood/ Surcharge Reduction & Sea Level Rise Resiliency Benefits

Flood/ Surcharge Reduction

Existing System

With Option 4b Tunnel

Legend: Surcharge Depth Above Crown of Modeled Pipe

3-4 ft. | 4-6 ft. | 6-8 ft. | 8-10 ft. | 10-12 ft. | 12-15 ft. | 15+ ft.

Sea Level Rise Resiliency

Existing System

With Option 4b Tunnel

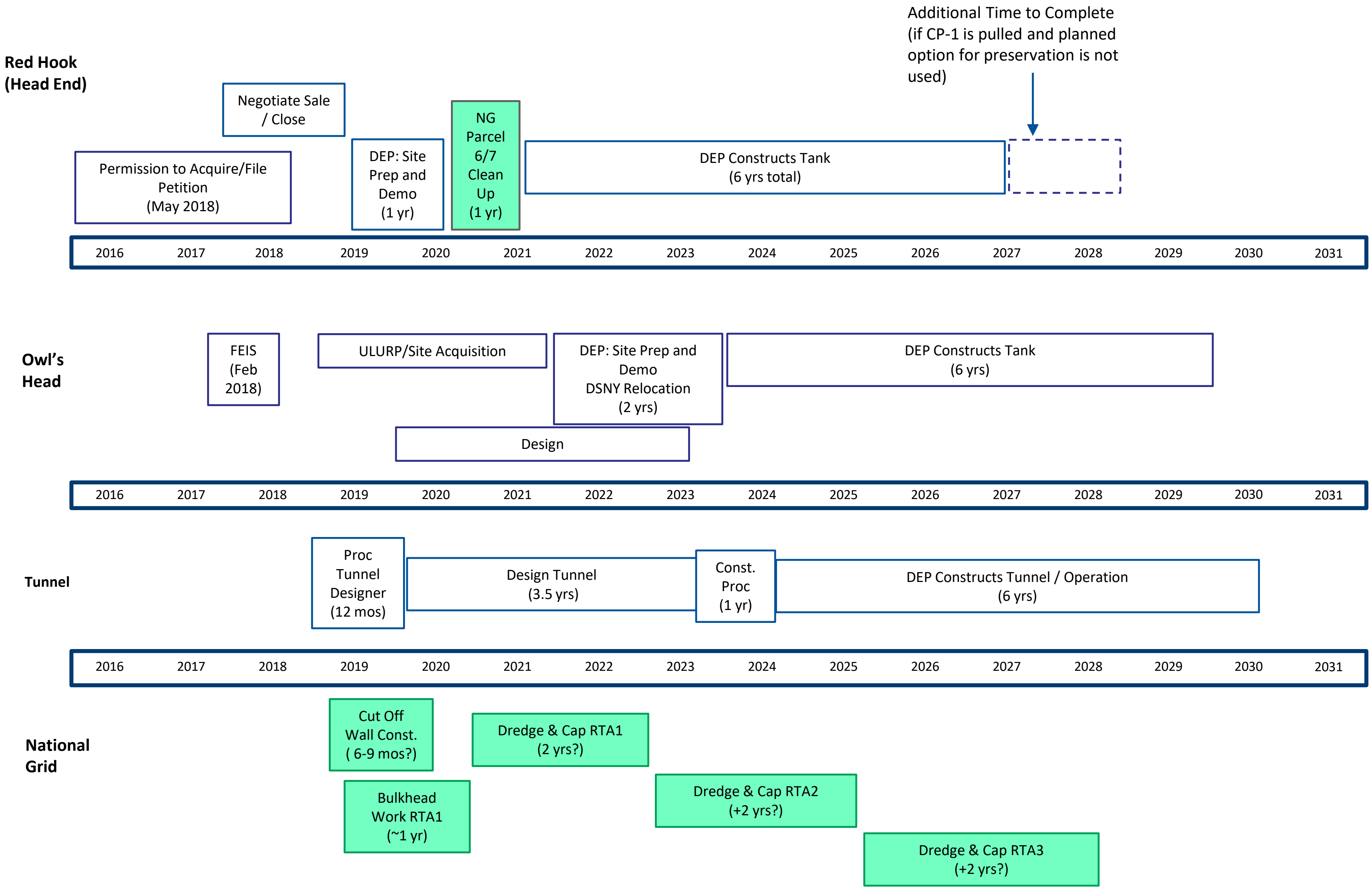
Legend:

Tidally Influenced Sewers for 5-Year DEP Storm at MHW + 58" SLR

CSO Performance vs. Baseline

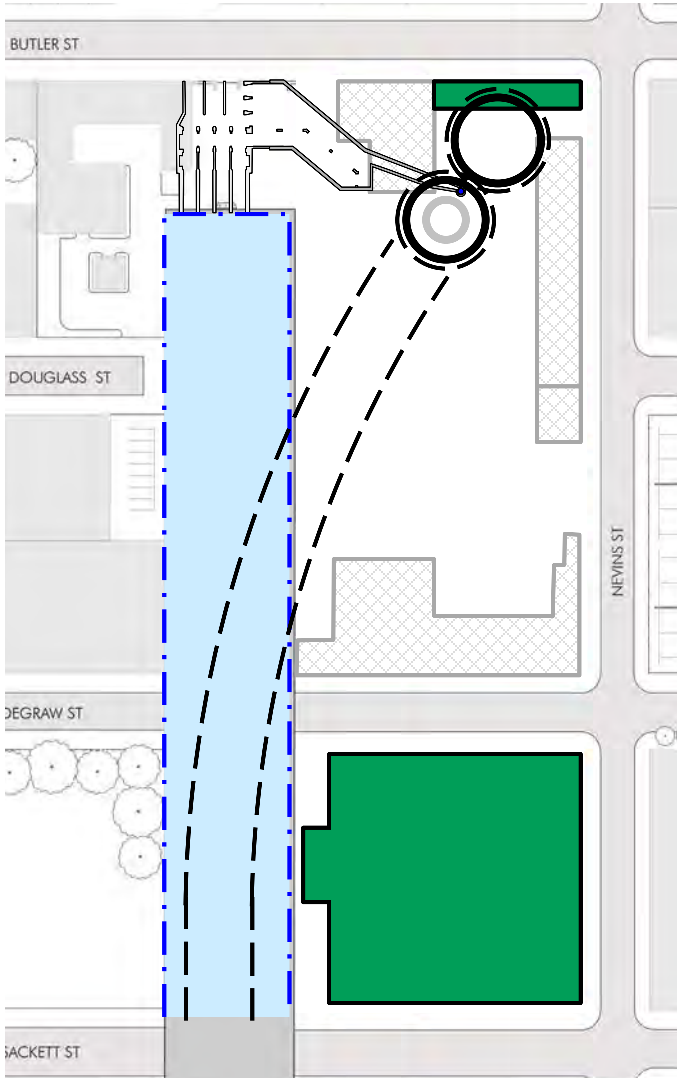
Summary of Typical Year (2008) Performance				
	Baseline	Option 1: Tanks Only	Option 3a: Phase 1 and OH Flooding Benefits	Option 4b: All Phases
Total Storage Volume (MG)		12	17.5	37.3
CSO Performance				
a. % CSO Captured at RH-034 and OH-007				
RH-034		75.4%	83.0%	93.4%
OH-007		84.6%	100.0%	100.0%
b. Annual Average Overflows (MG)				
RH-034	123.3	30.9	21.3	8.2
OH-007	63.2	9.7	0	0.02
RH-031	16.9	16.9	16.9	0
RH-030	16.4	16.4	16.4	0
RH-035	5.4	5.4	5.4	0
Other Overflows	19.3	19.3	19.3	4.8
c. Number of Activations				
RH-034		6	4	2
OH-007		4	0	1
Entire Canal Percent CSO Volume Reduction		**49%**	**56%**	**78%**

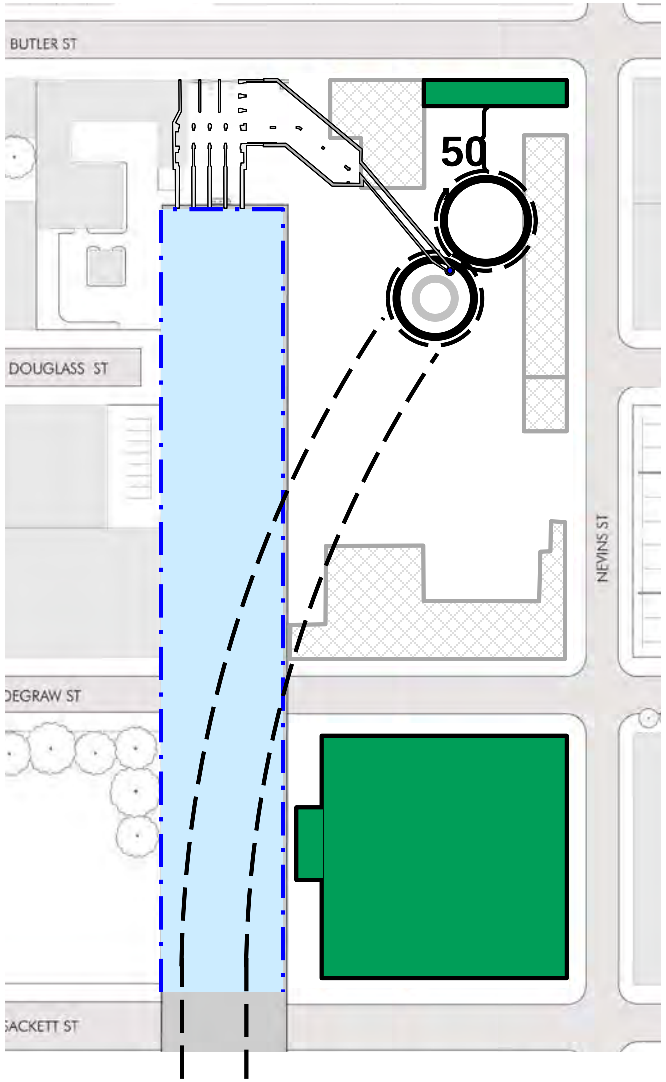
Timeline



Additional Time to Complete (if CP-1 is pulled and planned option for preservation is not used)
Red Hook (Head End)
Negotiate Sale / Close
Permission to Acquire/File Petition (May 2018)
DEP: Site Prep and Demo (1 yr)
NG Parcel 6/7 Clean Up (1 yr)
DEP Constructs Tank (6 yrs total)
2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031
Owl's Head
FEIS (Feb 2018)
ULURP/Site Acquisition
DEP: Site Prep and Demo DSNY Relocation (2 yrs)
DEP Constructs Tank (6 yrs)
Design
2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031
Tunnel
Proc Tunnel Designer (12 mos)
Design Tunnel (3.5 yrs)
Const. Proc (1 yr)
DEP Constructs Tunnel / Operation (6 yrs)
2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031
National Grid
Cut Off Wall Const. (6-9 mos?)
Bulkhead Work RTA1 (~1 yr)
Dredge & Cap RTA1 (2 yrs?)
Dredge & Cap RTA2 (+2 yrs?)
Dredge & Cap RTA3 (+2 yrs?)

- Location of Tunnel Launch and Dewatering Pumping Station shafts can be adjusted to accommodate preservation of 234 Butler Street





Next Steps

- Firm up Tunnel Program Scope, Cost and Schedule under existing Tank Design Contract
  - Construction staging / packaging and associated cost
  - P80 analysis on schedule
- EPA acceptance of Tunnel Program Alternative
  - Similar schedule and performance to ROD Tanks
  - Initiate formal negotiations with new milestones
- Procure new contract for detailed Planning and Design (12-18 months)
- Broadcast Tunnel Approach to other Stakeholders and Public